PB-215 722

Cellulose Degradation in Composting

Manhattan College

prepared for
Environmental Protection Agency

MARCH 1973

Distributed By:
NTIS
National Technical Information Service
U. S. DEPARTMENT OF COMMERCE

PB 215 722

EPA-R3-73-029
Ecological Research Series
March 1973

CELLULOSE DEGRADATION IN COMPOSTING

by

Raymond Regan, John S. Jeris, Robert Gasser,
Kevin McCann, and Joseph Hudek

Manhattan College
Environmental Engineering and Science Graduate Program
Civil Engineering Department
Bronx, New York

Grant No. EP-00161
Program Element 1D2063

Project Officer
C. C. Wiles
Solid Waste Research Laboratory
National Environmental Research Center
Cincinnati, Ohio 45268

Prepared for

Office of Research and Monitoring
U.S. Environmental Protection Agency
Washington, D.C. 20460

153

REVIEW NOTICE

The Solid Waste Research Laboratory of the National Environmental Research Center, Cincinnati, U.S. Environmental Protection Agency, has reviewed this report and approved its publication. Approval does not signify that the contents necessarily reflect the views and policies of this laboratory of of the U.S. Environmental Protection Agency, nor does mention of trade names or commercial products constitute endorsement or recommendation for use. The text of this report is reproduced in the form received from the Grantee.

BIBLIOGRAPHIC DATA SHEET

1. Report No. EPA-R3-73-029

2.

3. Recipient's Accession No. PB-215 722

4. Title and Subtitle
Cellulose Degradation in Composting

5. Report Date
March 1973

6.

7. Author(s) Raymond Regan, John S. Jeris, Robert Gasser, Kevin McCann, and Joseph Hudek

8. Performing Organization Rept. No.

9. Performing Organization Name and Address
Manhattan College, Environmental Engineering and
Science Graduate Program, Civil Engineering
Department, Bronx, New York

10. Program Element 1D2063

11. Res. Grant No.
EP-00161

12. Sponsoring Organization Name and Address
U.S. Environmental Protection Agency
Office of Research and Monitoring
Washington, D.C. 20460

13. Type of Report & Period Covered
Final Report

14.

15. Supplementary Notes

16. Abstracts
The purpose of the research investigation was to determine the optimum environmental conditions for the degradation of refuse using the composting process. Shake flasks and Warburg studies were used to scan wide ranges of environmental parameters to locate optimum conditions for continuous studies in three bench scale composters of 1.5 cubic feet capacity each. Close control of the following parameters was maintained: temperature, air, moisture, pH, nitrogen, and phosphorus. Temperature and residual oxygen were monitored electronically while other analyses were performed periodically. Optimum values of various environmental parameters are given. Free air space is suggested as a universal parameter for composting solid wastes from various sources. The use of recycle especially under winter conditions, is recommended. Due to its resistance to biological degradation, cellulose, a major component of paper, should be recovered rather than composted.

17. Key Words and Document Analysis. 17a. Descriptors

*Cellulose, *Degradation, Environmental tests, Environmental engineering, Refuse disposal, Temperature

17b. Identifiers/Open-Ended Terms

Solid waste disposal, Resource recovery, *Composting, *Cellulose degradation, Biological degradation

17c. COSATI Field/Group 13 02, 14 02

18. Availability Statement
Release to public

19. Security Class (This Report)
UNCLASSIFIED

20. Security Class (This Page)
UNCLASSIFIED

21. No. of Pages
154

22. Price
$6.00/$0.95

SUMMARY PAGE

Research Grant - EC 00161

Final Report on

"Cellulose Degradation in Composting"

Raymond Regan - Project Engineer
John S. Jeris - Project Director
Project Assistants; Robert Gasser,
Kevin McCann, and Joseph Hudek

Institution - Manhattan College
Environmental Engineering
and Science Graduate Program
Civil Engineering Department
Bronx, New York

January, 1971

Summary Statement

The purpose of the research investigation was to determine the optimum environmental conditions for the degradation of refuse using the composting process. Shake flasks and Warburg studies were used to scan wide ranges of environmental parameters to locate optimum conditions for continuous studies in three bench scale composters of 1.5 cubic feet capacity each. Close control of the following parameters was maintained; temperature, air, moisture, pH, nitrogen, and phosphorus. Temperature and residual oxygen were monitored electronically while other analyses were performed periodically.

Optimum values of various environmental parameters are given. Free air space is suggested as a universal parameter for composting solid wastes from various sources. The use of recycle, especially under winter conditions, is recommended. Leachate COD may offer a stabilization index for composted solids and provide a test for control during composting. Due to its resistance to biological degradation, cellulose, a major component of paper, should be recovered rather than composted.

CONCLUSIONS

1. Optimum composting of refuse, containing 60 to 70 percent paper, was obtained at a temperature of 59 ± 5C.

2. The composting rate of a synthetic refuse containing primarily paper was less than ten percent of the rate obtained for refuse.

3. The moisture content and free air space for optimum composting of mixed refuse were 67 and 30 percent, respectively.

4. Maximum thermophilic composting rates were obtained in a pH range between 7.5 to 8.5.

5. Under the conditions studied, 50 to 75 percent seed recycle was required to obtain maximum results in continuous composting experiments.

6. With mass turnover times of 4 to 5 days, the reduction of water soluble and base soluble components of refuse reached maximum levels of 68 and 28 percent, respectively.

7. A significant decrease in the composting rate occurred for refuse having greater than 75 to 80 percent paper.

TABLE OF CONTENTS

Page

Summary of Report

Conclusions

I. Introduction 1

II. Laboratory Procedures and Equipment 3
  A. General 3
  B. Bench Scale Composters 3
  C. Shake Flask Apparatus 10
  D. Warburg Respirometer 14

III. Data Analysis 18

IV. Preparation and Analysis of Solid Waste and Seed 20
  A. Solid Waste Substrate 20
  B. Seed 20
  C. Routine Analysis and Measurements 21
  D. Specific Analyses 22
  E. Solid Waste Characteristics 24

V. Results 26
  A. Bench Scale Composters 26
  B. Shake Flask Apparatus 38
  C. Warburg Respirometer 38
  D. Miscellaneous 48

VI. Discussion 50
  A. Temperature 50
  B. Moisture Content and Free Air Space 66
  C. Recycling Seed 77
  D. Degree of Stabilization of Compost 95
  E. pH 99
  F. Nutrient Requirements 111
  G. Refuse Storage Conditions 117
  H. Paper Content 122

VII. Summary 125

VIII. Appendix 129

IX. Bibliography 140

LIST OF TABLES

Table		Page
1	Schedule of Collection and Analyses of Gases by Monitoring System	9
2	Solid Waste Characteristics	25
3	Parameters Studied Using Bench Scale Composters	27
4	Summary of Data - Composter Run 8	28
5	Stabilization of Various Fractions of Refuse by Composting	31,32
6	Removal of Various Refuse Components by Composting	33
7	Nitrogen Recovery for Run 8	35
8	Comparison of Various Methods for Computing Mass Reduction	36
9	Mass Reduction Rate - Error Analysis	37
10	Parameters Studied Using Shake Flasks and Newsprint Medium	39
11	Parameters Studied Using Shake Flasks with Mixed Refuse	40
12	Purpose and Conclusions of Shake Flask Studied	41
13	Summary of Warburg Runs	42,42a
14	Comparison of Composting Rates From Warburg and Bench Scale Composters	47
15	Composting Rates Obtained Using Newsprint	53
16	Composting Rates Obtained Using Stabilized Mixed Refuse	55
17	Chemical Analysis of Mixed Refuse	56
18	Composting Rates Using Mixed Refuse in Shake Flasks	57
19	Composting Rates Using Mixed Refuse in Bench Scale Composters	60
20	Temperature Conditions for Optimum Composting of Cellulolytic Solid Wastes	65

LIST OF TABLES
(Continued)

Table Page

21 Reported Optimum Moisture Contents 67

22 Optimum Moisture Content of High Rate Mechanical Composting 68

23 Optimum Conditions for Composting Municipal Refuse.. 74

24 Effect of Recycle Using Bench Scale Composters 88

25 Composition of the Organic Fraction of Mixed Refuse 95

26 Removal of COD from Leachate by Composting 96

27 Effect of pH in Bench Scale Composters 106

28 Effect of Storage Conditions - Warburg Run 13 119

29 Effect of Storage Conditions as Function of Seed Recycle 121

30 Mixed Refuse Batches Prepared for Warburg Run 14 ... 122

31 Environmental Conditions for Optimum Composting 125

32 Average Reduction of Mixed Refuse by Composting 126

LIST OF FIGURES

Figure Page

1 Outline of Procedure for Obtaining Experimental Results 4

2 Laboratory Composter System 5

3 Photographs of Bench Scale Composters 7

4 Effluent Gas Collection and Analysis System 8

5 Shake Flask Compost Apparatus 11

6 Photograph of Shake Flask Apparatus 12

7 Shake Flask Detail 13

8 Warburg Apparatus 15

9 Typical Example of Warburg Data 44

10 Probability Plot of Warburg Statistical Analysis 46

11 Organic Carbon in Mixed Refuse 49

12 The Effect of Temperature On Oxygen Uptake in Composting 51

13 Carbon Dioxide Production Vs. Temperature for Cellulolytic Materials (Newsprint and Stabilized Mixed Refuse) 54

14 Carbon Dioxide Production Rate Vs Temperature for Cellulolytic Materials (Result Comparison) 58

15 Effect of Temperature on Oxygen Consumption Rate For Mixed Refuse 59

16 Rate of Change of Carbon Dioxide Production Vs Temperature Using Cellulolytic Material 63

17 Rate of Change of Composting Vs Temperature Using Mixed Refuse 64

18 Moisture Content Vs Free Air Space for Organic Solid Wastes 70

19 Oxygen Consumption Rate Vs Moisture and Free Air Space 72

20 Moisture Content for Increasing Paper 75

LIST OF FIGURES
(Continued)

Figure Page

21 Effect of Seed Concentration on the Initial pH 80

22 Effect of Seed Concentration on the Oxygen Uptake Rate at 50.8°C 81

23 Effect of Seed Concentration on the Oxygen Uptake Rate at 59.6°C 82

24 Typical Oxygen Consumed Data (Run 8 Composter 1) ... 85

25 Typical Oxygen Consumed Data (Run 8 Composter 2) ... 86

26 Typical Oxygen Consumed Data (Run 8 Composter 3) ... 87

27 Effect of Seed Concentration on the Average Oxygen Consumation Rate 90

28 Effect of Seed Concentration on Bulkweight.......... 92

29 Effect of Seed Concentration on Bulk Volume 93

30 Effect of Mass Turnover Time on Leachate Removal ... 98

31 Temperature and pH Vs Time for Windrow Composting .. 100

32 Effect of pH on Oxygen Consumption and Carbon Dioxide Production Rate 102

33 Effect of pH on the Oxygen Consumption Rate (Bench Scale Composter) 104

34 Effect of pH on the Oxygen Consumption Rate (Warburg Run 10) 107

35 pH Vs Titrant Volume 109

36 Variation of pH During 24 Hour Feed Cycle 110

37 Effect of Nutrients on Reaction Rate 112

38 Effect of Nitrogen on Oxygen Consumption 113

39 Effect of Phosphorus on pH and Oxygen Consumption Rate 115

40 Effect of Refuse Storage on Composting Rate 118

41 Effect of Paper Content on Oxygen Consumption Rate.. 124

I INTRODUCTION

A review of the most common solids disposal methods utilized in many communities throughout the United States indicates present disposal techniques, if not already antiquated and inadequate, are quickly becoming so. (1) Too often, the burning of wastes in open dumps or in poorly designed incinerators is a major source of air pollution. Open dumps and sanitary landfills are polluting surface and ground waters and may be public health hazards. Meanwhile, the unavailability and rising cost of land near urban areas has made dumps and landfills increasingly expensive and impractical.

The real solution to a solid waste problem must envelop the concept of total environmental control. The answer must be a method which will neither contaminate the water, pollute the atmosphere or desecrate the land. Composting has the potential for providing a rational approach to solving the solid wastes dilemma without polluting the air or water resources.

Composting is one of the oldest solid waste disposal methods known to man. This biological treatment process has the capability of converting municipal refuse and other organic waste solids to a product which: (1) has a lower bulk volume than the original waste, (2) is stable, and (3) has the potential of being recycled into the ecological sphere without destruction of its high energy value. Reuse of potential raw materials such as found in solid wastes will receive greater attention and make a considerable impact on future treatment and disposal methods.

Composting, as a method of solid waste disposal, has had a poor history. In the 1920's and 1930's composting plants were more common in the United States, but profiteering and mismanagement too often brought on failure. The profit motive introduced by saleable products, helped bring unjust discredit to the process. Further, lack of knowledge and disregard of scientific principles effecting the composting process helped bring poor and inefficient operation to many of the early plants.

Recently there has been an increasing interest in composting. However, over the past thirty years the character of household refuse has changed. The quantity of paper and paper products discarded has increased drastically thus making solid waste more resistant to biological treatment. Presently municipal refuse typically consists of from 50 to 80 percent paper.

During the first two and one-half years, the Manhattan College solid waste project concerned the composting of a synthetic waste composed of 100 percent paper, a cellulolytic material. It was the degradation of cellulose, the major component of paper, which was considered to be the rate limiting step in composting. This earlier work has been reported (2) and is discussed presently in the light of more recent results.

It was found during the earlier work that cellulose degrades slowly and it was concluded that the significant improvements required which would result in an economical composting process would have to be of such a magnitude that it was beyond optimization of cellulose alone. For this reason, in January, 1969, the direction of the research was altered to determining the environmental conditions necessary for optimum degradation of typical municipal refuse. The rates achieved using a mixed refuse were an order of magnitude greater than that of the paper substrate.

Composting seems to have potential which has never been fully exploited (3). It is hoped that the results of this investigation will supply the basis for a scientific approach to the composting process on a larger scale. This information will also help in making a more realistic economic analysis of composting.

An economic re-evaluation not only of composting, but also the other solid waste disposal processes should encompass all costs, including effects on the environment. Correctly handled, composting presents a solid waste treatment method which has less detrimental impact on the ecology than the other commonly used solid waste disposal methods.

II LABORATORY PROCEDURE AND EQUIPMENT

A. General

Composting investigations were performed using three major experimental systems: (a) bench scale composters, (b) shake flask apparatus and (c) Warburg respirometer. The continuously fed experiments were made using three bench scale composters. Batch fed studies were carried out using the shake flask apparatus, and the Warburg respirometer. Each of these apparatuses allowed for close control of the desired environmental parameters and was sufficiently flexible to operate over wide ranges of conditions. The general procedure used for obtaining results during the research is outlined in Figure 1. The research was carried on in three major steps.

Step 1 Samples of waste material were placed into the battery of bench scale composters. The composters were operated until the microorganisms present in the waste were assumed to have become acclimated at certain desired conditions. Significant quantities of composted material to be used as seed were produced in this manner.

Step 2 Wide ranges of chemical and physical parameters were investigated in batch fed experiments using the shake flask and Warburg apparatus. Samples of waste material were mixed with significant amounts of seed as prepared in Step 1 to minimize lag phases in obtaining preliminary experimental results.

Step 3 Using the most promising results of Step 2, narrower ranges of the various study parameters were extensively examined in the bench scale composters on a continuous feed basis. In this manner, the optimum ranges were defined for various environmental factors in composting typical mixed refuse.

B. Bench Scale Composters

A schematic drawing of the experimental bench scale composting system is shown in Figure 2. Each of the three composters used was a horizontal stainless steel cylinder, 12 inches in diameter, two feet long with a total volume of 1.5 cubic feet.

Figure 1

OUTLINE OF PROCEDURE FOR OBTAINING EXPERIMENTAL RESULTS

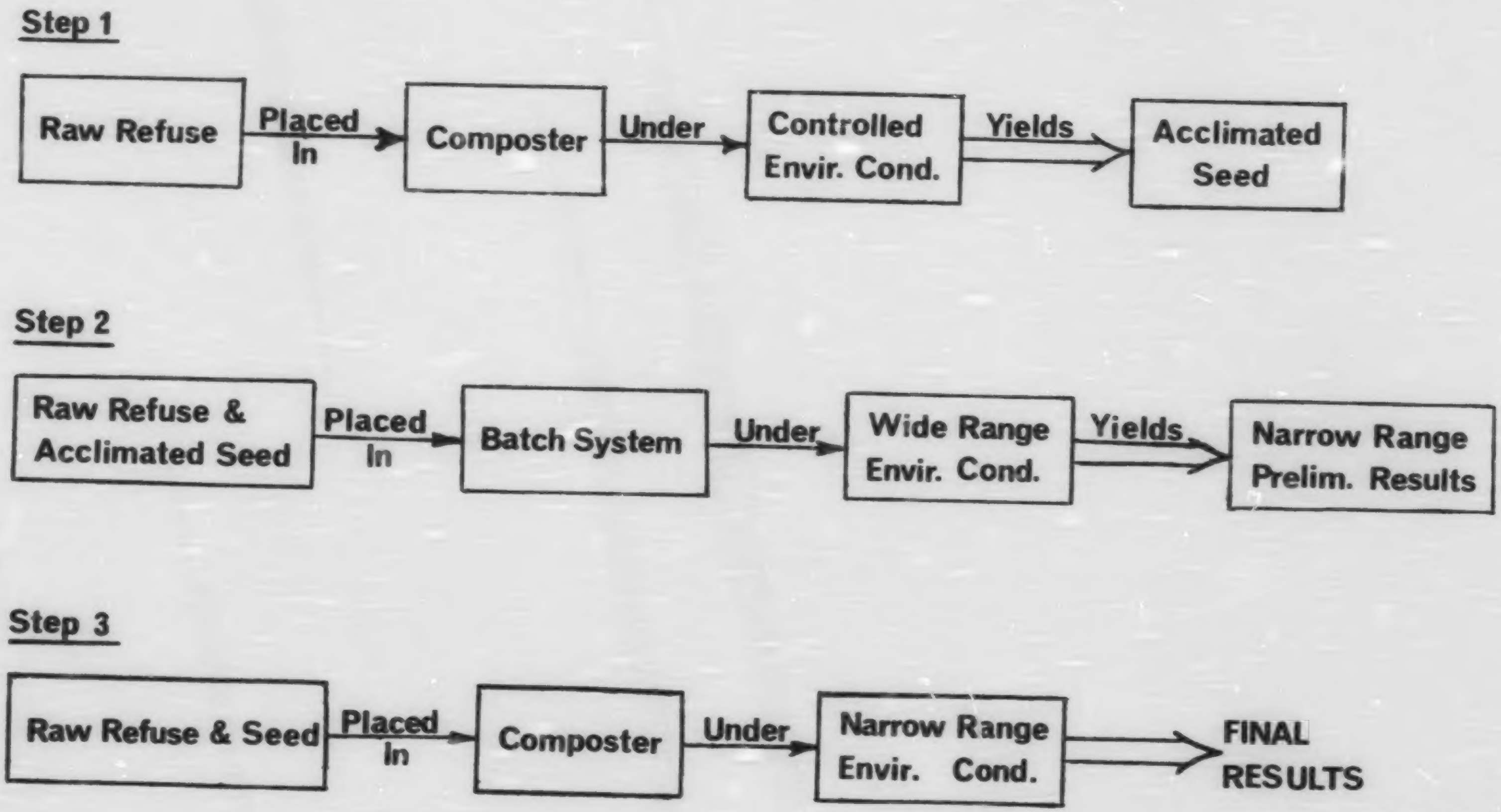
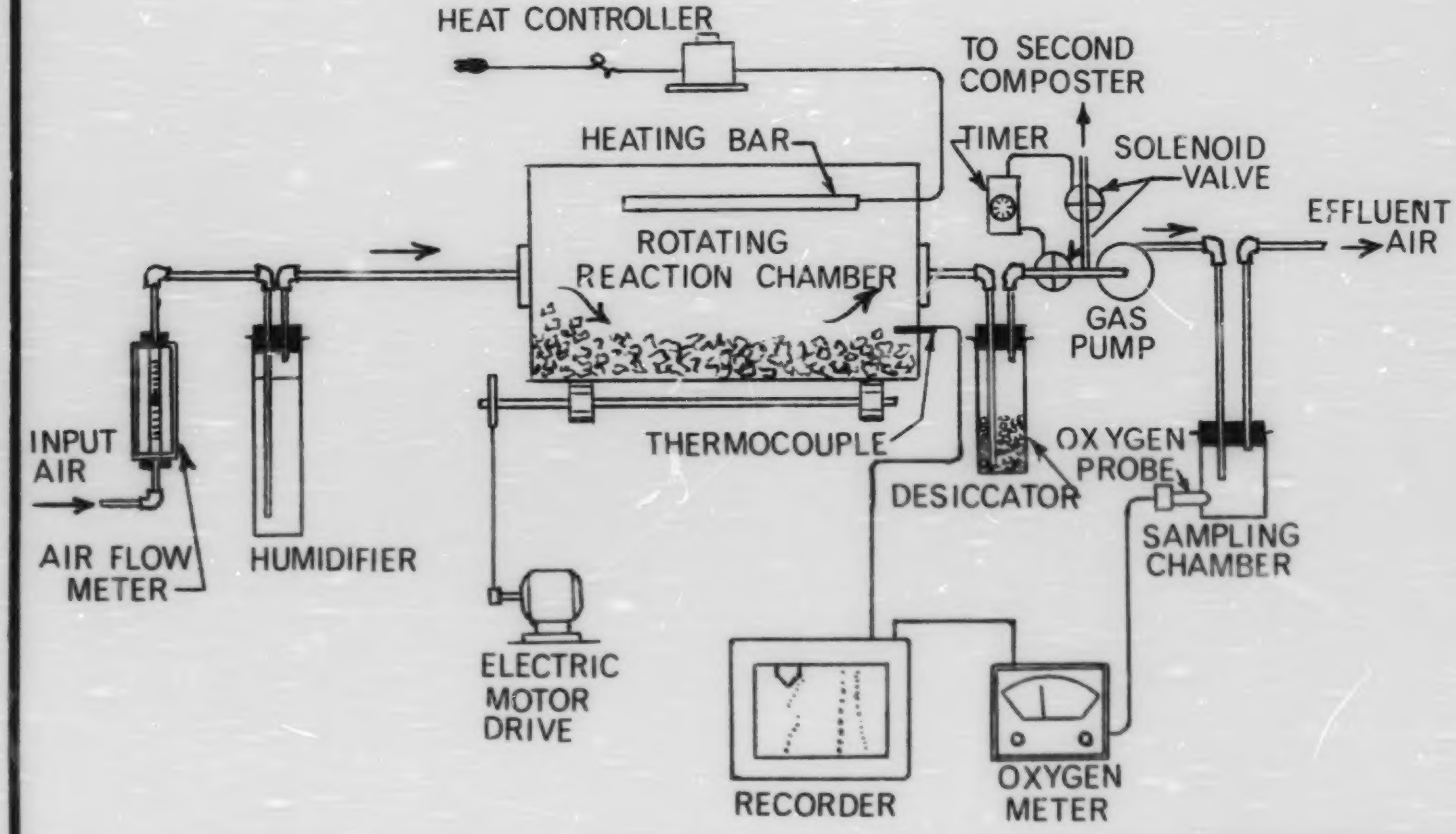


FIGURE 2

LABORATORY COMPOSTER SYSTEM



Under operating conditions, an eight inch port on the wall of each cylinder made access convenient for loading, sampling and cleaning. Waste material tended to adhere to the walls during operation. The walls were scraped daily by hand and the material manually mixed with the remaining solids.

Each composter contained a total weight of 1,000 to 3,000 g and filled about one-half the cylinder volume. Photographs of two of these units in operation are shown in Figure 3.

Continuous heat was supplied by an electric heating rod suspended in the air space directly over the composting mass. The temperature was maintained at a constant level by controlling the power to the heating rod with a rheostat. Excess heat losses were reduced by placing the battery of composters in a walk-in type incubator maintained at 37C and by using insulation around each cylinder. In this manner, the control of the temperature was not dependent on microbial activity. The temperature could be adjusted to any desired level and used as a controlled variable for studying its effect on composting efficiency.

Mixing and aeration of the material was provided by intermittent rotation of the cylinder. During these studies the drive motor was activated to allow one rotation of each cylinder for time cycles of 30 minutes to three hours.

Air was supplied to each unit through a rotometer at a rate sufficient to maintain an oxygen residual of at least ten percent in the effluent gas. Continuous analysis of the residual oxygen of each unit was measured automatically every four hours by an oxygen probe placed in the sampling chamber and monitored by a multipoint strip chart recorder. Daily samples of gas were also taken and analyzed by gas chromatography to determine the carbon dioxide content of the effluent.

A line diagram of the automatic effluent gas collection and analysis system is shown in Figure 4. Analysis of composter effluent gases required two hours of a four hour programmed cycle. During this time, gas was pumped from the effluent line of each

Figure 3

PHOTOGRAPHS OF BENCH SCALE COMPOSTERS

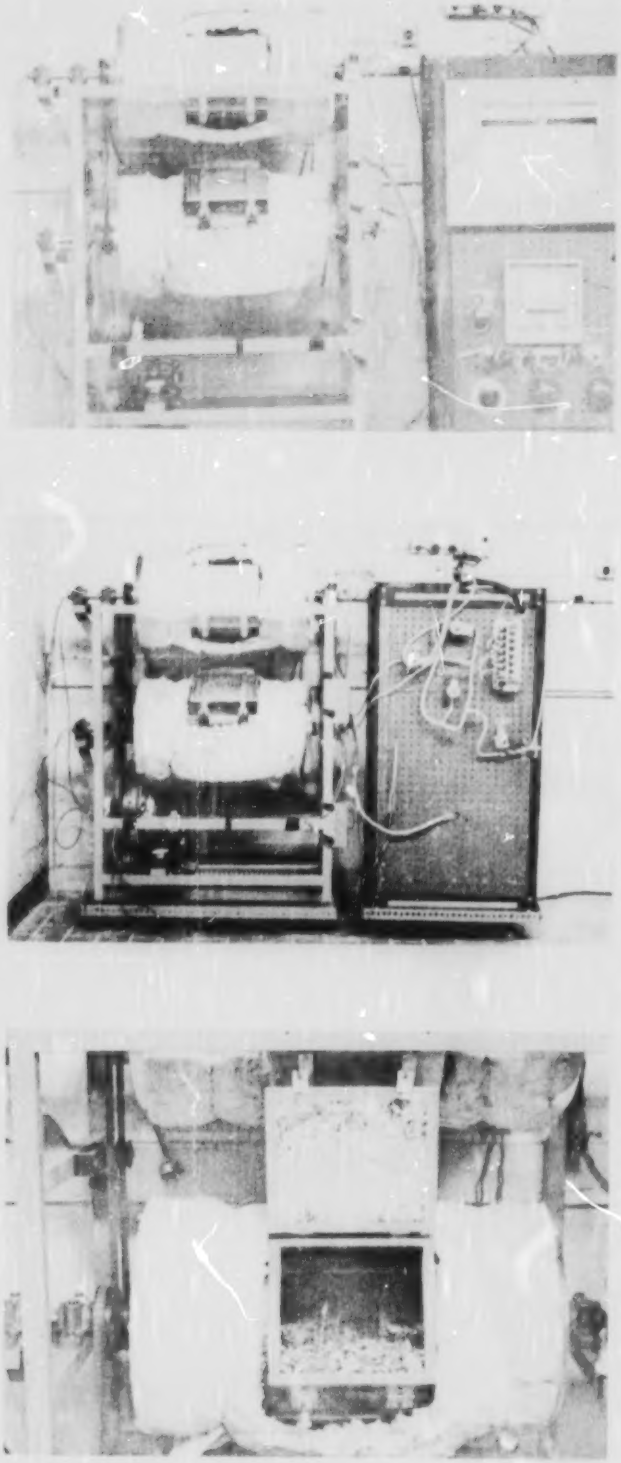
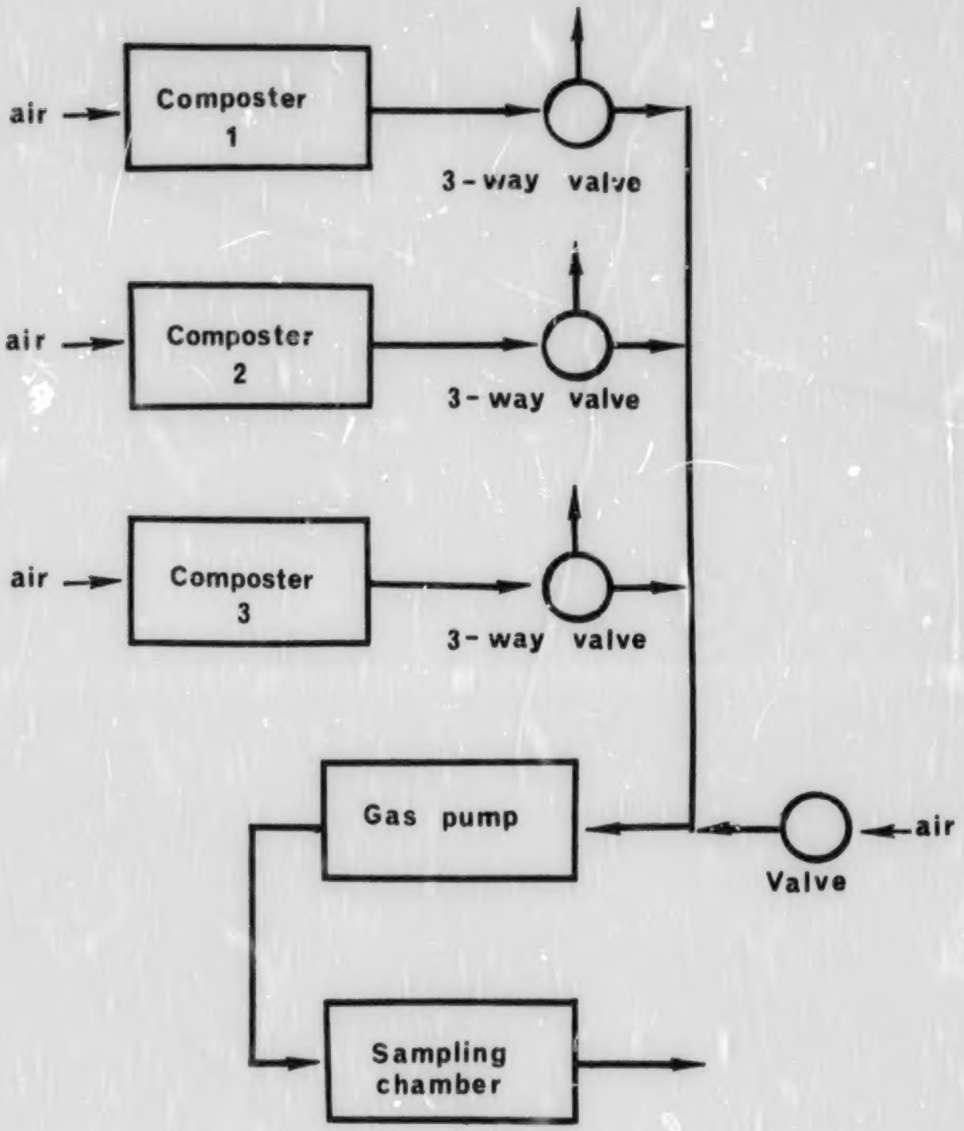


Figure 4

EFFLUENT GAS COLLECTION AND ANALYSIS SYSTEM



composter in sequence and directed through the gas sampling chamber. The residual oxygen content from each of the three composters was measured. Table 1 summarizes the program for the collection and analysis of the gases by the monitoring system.

Table 1

SCHEDULE OF COLLECTION AND ANALYSES OF GASES BY MONITORING SYSTEM

Step	Time (minutes)	Operation
1	0	Gas pump on
2	0	Air valve open
3	10	Air valve closed #1 3-way valve closed
4	40	#1 3-way valve closed, air valve open
5	50	Air valve closed, #2 3-way valve open, #2 3-way valve closed
6	80	Air valve open
	90	#3 3-way valve open, #3 3-way valve closed
7	120	Gas pump off
8	240	Gas pump on and entire cycle repeats

The air valve, when open, allowed air to be pumped through the sampling chamber. Its purpose was to flush any residual effluent gases from the sampling chamber. As a result a line of zero percent oxygen consumed was established on the strip chart recorder between each of the three gas samples, thus allowing standardization of the oxygen probe. The recorder plotted individual points on a 75 second cycle. This enabled approximately 24 readings of the effluent gases from each composter to be obtained during each sampling period. Usually 16 of the points were representative of an equilibrium condition.

The gas pump was used to insure the passage of effluent gases through the sampling chamber. The composters were intended to be airtight, however, some leaks were discovered with time. The pumping rate of the composter effluent gases was adjusted to be lower than the incoming air rate in order to eliminate the possibility of air leaking into the composters. The three way valves, one connected to each of the three composters, had exit air vents which allowed the effluent gases to be expelled into the atmosphere when gas samples were not being analyzed.

C. Shake Flask Apparatus

The shake flask apparatus was composed of four incubators each containing eight shake flasks. The flasks were mounted on the arms of two Burrell wrist-action shakers which were located between the incubators as shown in Figure 5, and with photographs in Figure 6.

Each incubator was 25" X 20" X 16" and constructed of masonite with two inches of rock wool insulation on five sides. The sixth side was an observation door. A heating rod mounted in the incubator provided heat which was regulated by a rheostat.

In Figure 7, a shake flask is shown in greater detail. The flasks used were 500 ml Erlenmeyers and sealed with a rubber stopper containing a glass tube which served as a gas sampling port. Approximately every 3 to 4 hours during a run, a gas sample was taken from each flask, for analysis and the flask was completely aerated. The Burrell shaker provided a tumbling action for a two minute period every two hours. A maximum of 32 flasks, at four different temperatures, could be set-up at one time ensuring coverage of a wide range of conditions.

To initiate a shake flask study, acclimated seed was obtained from the bench scale composters and placed in each flask together with refuse, nutrients and additives to produce the desired conditions. Duplicate flasks were normally set-up for each study condition. Controls were used to compare the activity of the seed material with those containing refuse and other test additives. As a run progressed, nutrients and additional substrate

FIGURE 5

SHAKE FLASK COMPOST APPARATUS

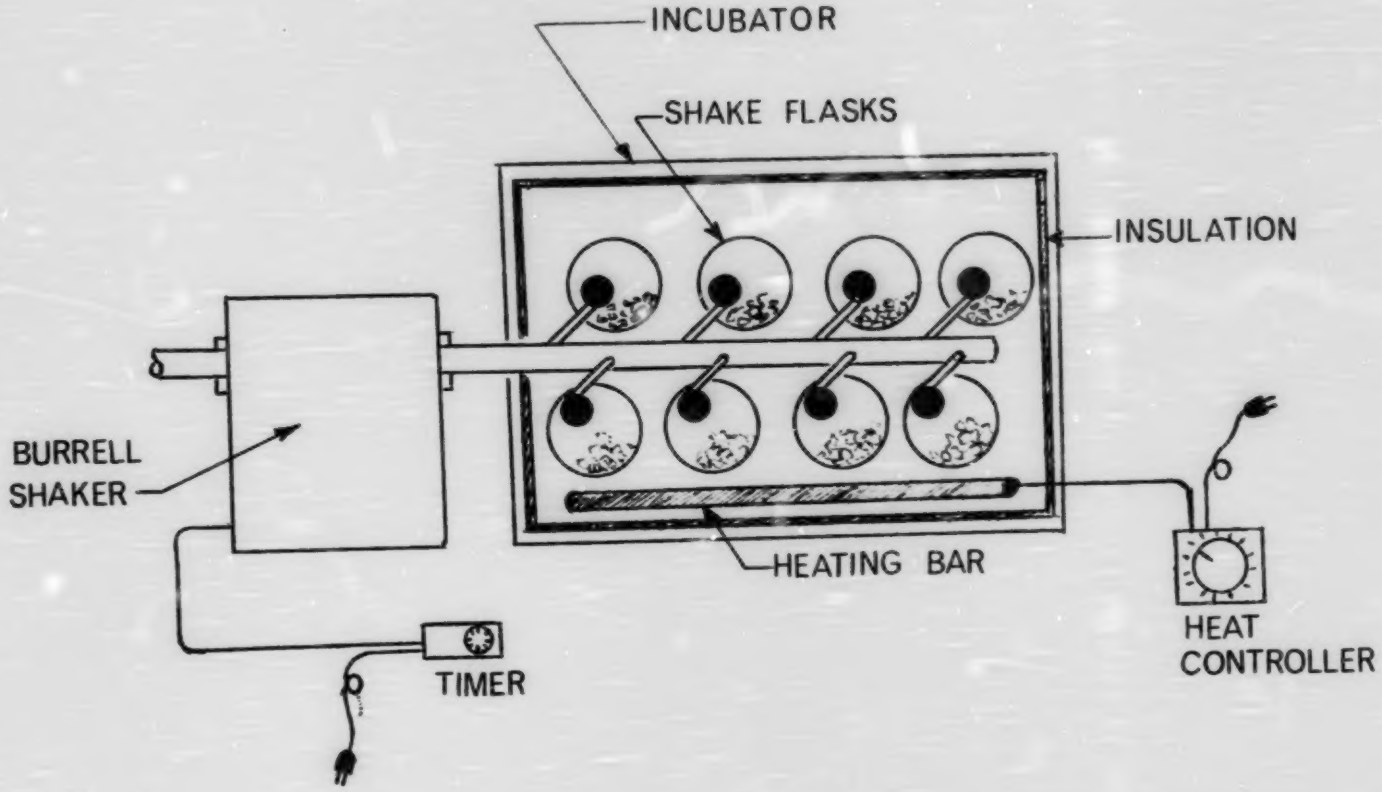


Figure 6

PHOTOGRAPH OF SHAKE FLASK APPARATUS

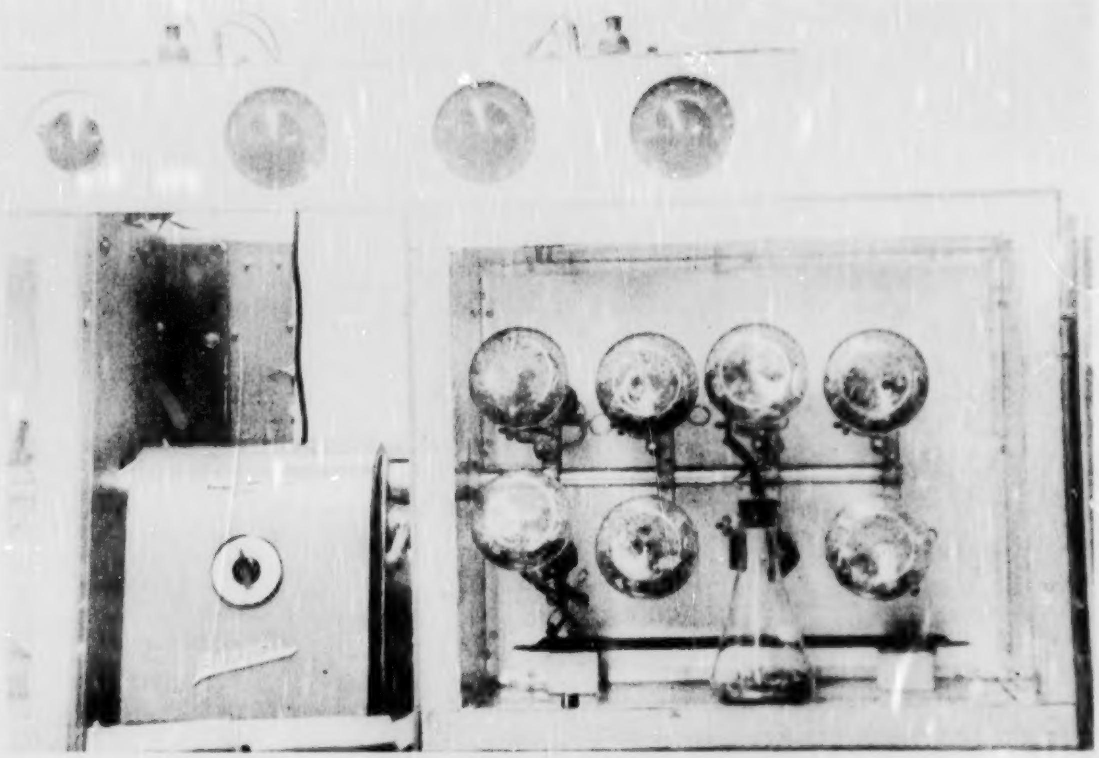
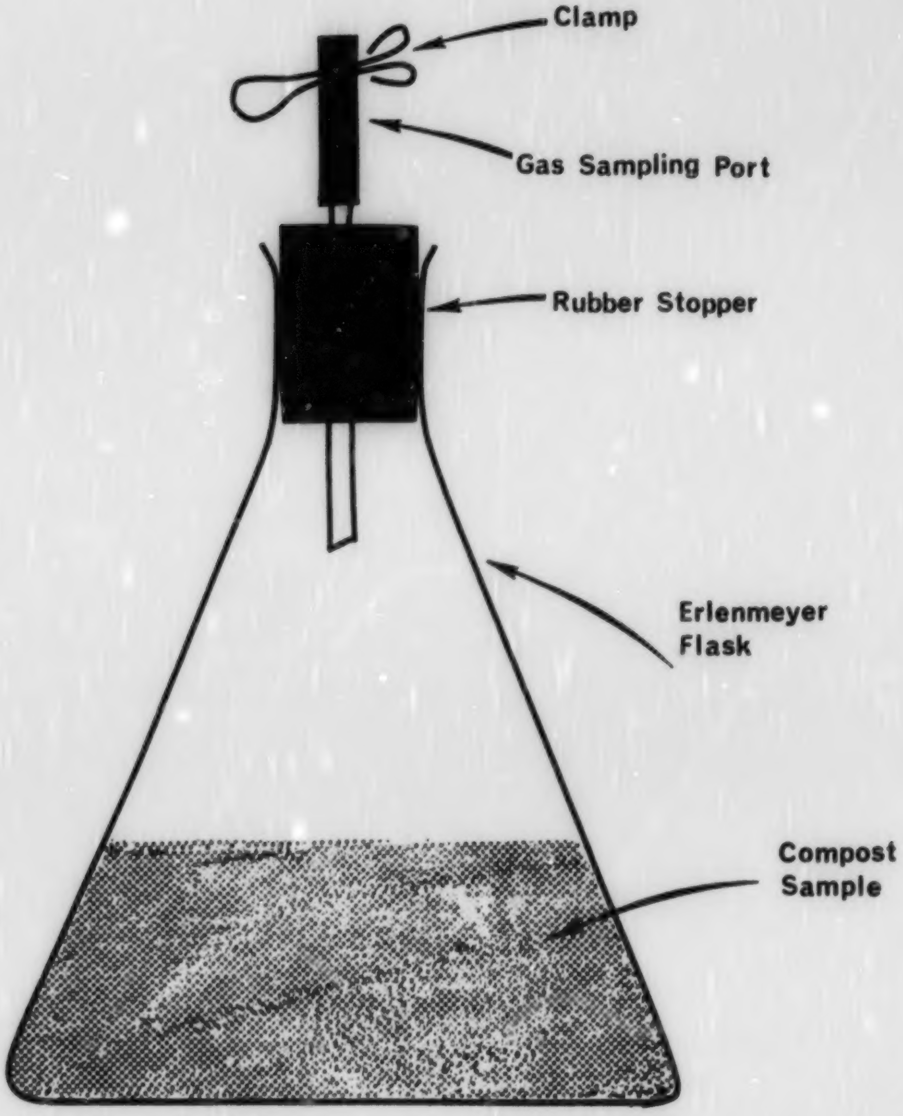


Figure 7

SHAKE FLASK DETAIL



were added as necessary. Generally, a run was concluded after one week of data collection.

D. Warburg Respirometer

The Warburg Respirometer was used to determine the total oxygen consumption and oxygen consumption rates of the various solid wastes used in the investigations. The Warburg apparatus (4) shown in Figure 8, measured manometrically changes in the gaseous content within the closed system, containing the biologically active mass. As oxygen was consumed by the aerobic microorganisms, the carbon dioxide produced was absorbed by potassium hydroxide within the center well of the flask. The resulting decrease in pressure within the closed system is related to the oxygen consumed by the microorganisms present. This type of apparatus is ideally suited for composting studies, in which a high degree of environmental control and a wide range of conditions require study. In the apparatus, 18 flasks, or separate study systems could be set up at one time. A sample of material was placed in a flask at a specified moisture and temperature level. Since each flask was opened only periodically for reaeration, evaporation losses from the sample were minimized for the duration of the test period.

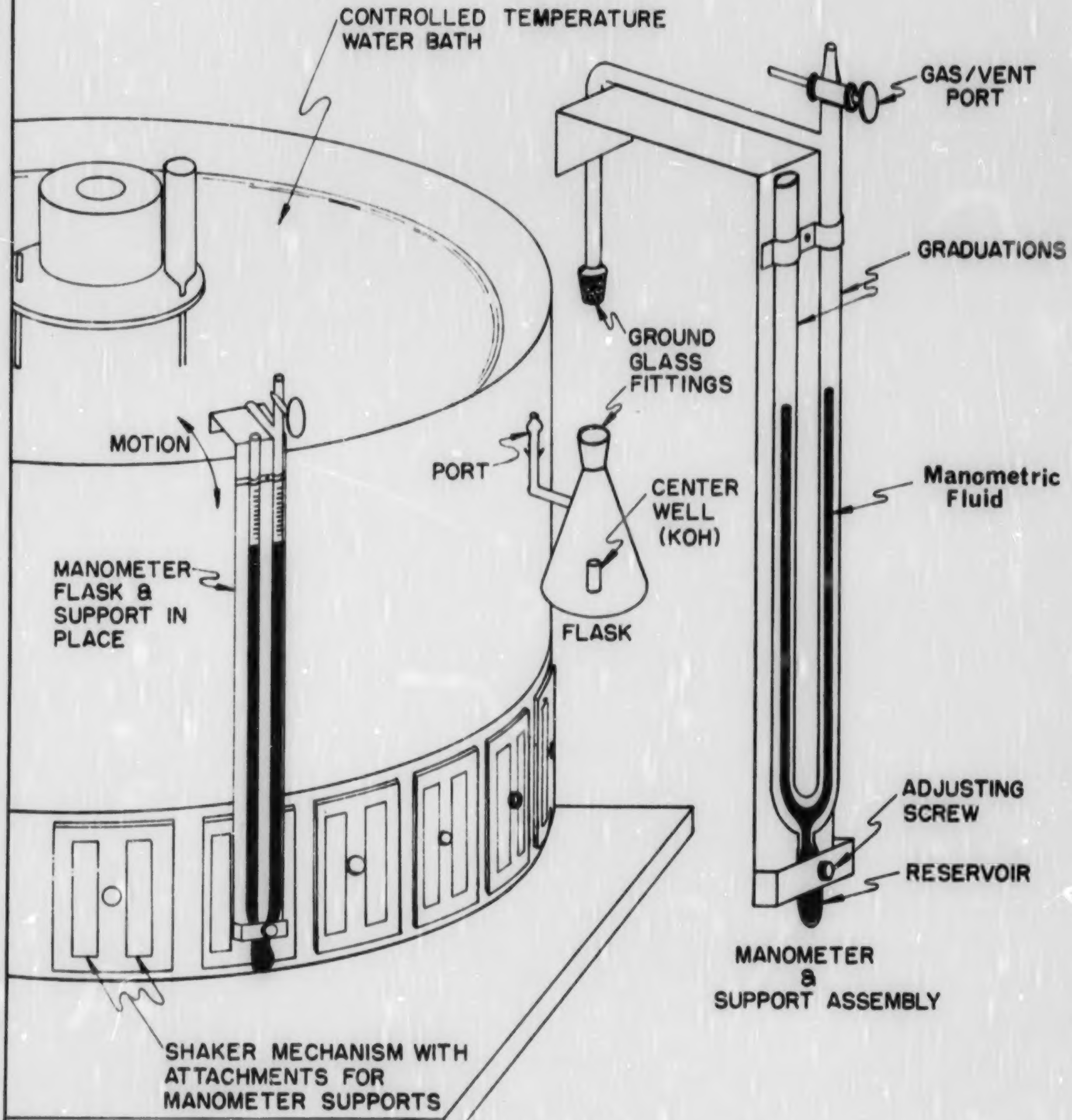
The use of the Warburg apparatus has frequently been applied to environmental and pollution problems. The aerobic biological activity for activated sludge processes has been typically determined at 20C (5). Warburg studies of anaerobic treatment processes have been performed at a temperature of 37C (6). Previous composting investigations using the Warburg apparatus are limited (7).

The basic operating procedure for application of the Warburg respirometer to the composting research was as follows:

1. Approximately 100 grams of material containing desired amounts of mixed refuse and acclimated seed (both on a dry basis), from a continuously fed laboratory composter operating near the appropriate condition, were blended briefly at a slow speed to insure a homogeneous mixture. Sufficient ammonium chloride and potassium phosphate were added prior to blending to provide the required nutrients.

Figure 8

WARBURG APPARATUS


CONTROLLED TEMPERATURE WATER BATH
GAS/VENT PORT
GRADUATIONS
GROUND GLASS FITTINGS
MOTION
PORT
CENTER WELL (KOH)
Manometric Fluid
MANOMETER FLASK & SUPPORT IN PLACE
FLASK
ADJUSTING SCREW
RESERVOIR
MANOMETER & SUPPORT ASSEMBLY
SHAKER MECHANISM WITH ATTACHMENTS FOR MANOMETER SUPPORTS

2. The initial pH and moisture level of the mass were determined.

3. The sample was divided into smaller portions in which the equivalent dry weight used in each flask was 1.4 grams. Sufficient water and chemicals were added to each portion to attain the desired experimental conditions.

4. Duplicate samples, at a given set of conditions, were placed in 125 ml Warburg flasks. In the center well of each flask 1 ml of 20 percent potassium hydroxide was placed for carbon dioxide absorption.

5. The flasks were attached to mercury-filled manometers and placed in the constant temperature bath at 50.8 or 59.6C.

6. The Warburg apparatus was placed in motion and the flasks were allowed to reach a constant temperature with the system open to the atmosphere for at least 10 minutes.

7. The flasks were sealed. Manometer readings were made.

8. Because of the great oxygen demand caused by the large amount of organic matter present in the sample, special reaeration procedures were required during the run. If the vacuum was released in the flask by simply opening the vent and allowing air to be pulled into the flask, the result, after relieving the pressure several times, would be an increase in the nitrogen concentration in the system. The problem of nitrogen buildup was minimized by the following procedure:

a) The flasks were flushed several times with a rubber bulb so that more oxygen was made available to the aerobic microorganisms.

b) A procedure was developed in which oxygen was saturated with water at the experimental temperature and placed in a tube. As reaeration was required the tube was connected to the Warburg flasks. The vacuum created in the flask due to aerobic activity would be relieved by flow of oxygen from the tube. Using this system, the oxygen concentration within the sealed flask could be no greater than that in atmospheric air.

9. The manometer, which gives the change in pressure in each flask, was measured at 15 to 30 minute intervals for the first 12 to 14 hours of the Warburg run. Typically the cumulative oxygen consumption data for these systems followed a linear rate for the first eight to ten hours; the rate after this time decreased. The Warburg run was terminated after 24 to 28 hours.

10. The flask constants relating the manometric deflections for mercury to the oxygen consumption were calculated at 50.8 and 59.6C to be approximately 0.15 to 0.16 mg O_2/g dry mass when using samples containing a total of 1.4 g dry mass. The oxygen uptake rate was determined by measuring the rate of change of the total oxygen consumption for the first eight to ten hours of the run. The results were correlated to the various environmental factors imposed on each sample.

11. In some of the warburg studies, samples were removed during the first 12 to 14 hours of the run to determine the carbon dioxide production rate. The carbon dioxide concentration of the potassium hydroxide in the center well of the flask was measured using a Beckman carbon analyzer, Model No. 915. The carbon dioxide measured was assumed to be linearly produced during the period of linear oxygen production.

III DATA ANALYSIS

The experimental results of each continuously fed composter run were determined from the average values of at least 10 days of operation at the desired conditions. The experimental results obtained from the batch operated experiments including use of the shake flasks or Warburg apparatus, were for runs extending typically from 1 to 7 days. The composting rates obtained from each of the three laboratory systems, operating under similar environmental conditions, were compared whenever possible.

Computer programs were developed to facilitate the comparisons and calculations of the experimental results. Several programs were used to analyze the data collected from the continuously operated composters, the shake flask apparatus and the Warburg respirometer. These computer programs were used to calculate the following:

A. Bench Scale Composters

1. Oxygen consumption and carbon dioxide production; plotted simultaneously with time and rates computed.
2. Respiration quotient; equal to the ratio of carbon dioxide produced and oxygen consumed.
3. Bulk density of refuse before and after treatment.
4. Reduction of volatile matter.
5. Removal of individual components present in mixed refuse including; lipids, crude fiber and protein.
6. Molecular weight (calculated) and oxygen demand of mixed refuse based on the components removed - See Appendix.
7. Comparison of the four methods used to determine the solid waste reduction rates in order to ascertain the reliability of each method as a measure of composting efficiency.

B. Shake Flasks

1. Carbon dioxide production rates plotted with time.
2. Average composting rate; determined by method of least squares.

C. Warburg Respirometer

1. Statistical analysis of oxygen consumption rates. Included in the results were the confidence limits and "safe" sample size for the experimental conditions.

D. Miscellaneous

1. A theoretical analysis, showing the effect of paper content on the moisture requirements of several types of organic solid wastes including mixed refuse, sewage sludge, and beef feed lot wastes.

IV PREPARATION AND ANALYSIS OF SOLID WASTE AND SEED

A. Solid Waste Substrate

The solid waste used as feed for the research included newsprint, typical mixed refuse containing 60 to 70 percent paper and composted mixed refuse from Altoona, Pennsylvania. The cellulose content was significant in each of these substrates.

Two methods were employed for obtaining mixed refuse. Initially, batches of urban refuse were collected bi-weekly and stored in metal containers until needed for experimental use. This method was inadequate because the chemical characteristics of the refuse varied from batch to batch. Also the refuse deteriorated during storage making comparison of the experimental results difficult. To improve the degree of control, a synthetic refuse, with characteristics similar to municipal solid waste was prepared in the laboratory. It consisted of wastes from the college cafeteria, super-market wastes and newsprint. Typically meat and fish scraps, lettuce and other vegetable trimmings were used.

The solid waste feed was prepared by cutting and grinding the waste materials with a garden shredder. Materials were cut to a particle size no greater than one quarter of an inch. Since the waste materials contained insufficient nutrients, nitrogen in the form of ammonium chloride was added. The wastes were also supplemented with phosphorus. The moisture content was adjusted to suitable levels for composting with tap water. It was assumed that the tap water supplied necessary trace elements.

B. Seed

Purified cultures growing on cellulose in liquid media were used as seed for the start-up of some of the composting studies involving newsprint. Other experiments using newsprint were performed using a maximum of 10 percent composted mixed refuse as seed. Batch fed studies were made on composted refuse, as it was received. No additional seed material was used, since suitable microorganisms were assumed to have remained in the composted waste. The use of high recycle in the studies involving mixed refuse in batch and continuously fed composters made use of supplemental seed material unnecessary.

C. Routine Analyses and Measurements

In addition, to the continuous record of residual oxygen concentrations of the effluent gas of each of the bench scale composters, other physical and chemical parameters were measured routinely. The measurements made during active composting included mass temperature, air supply rate, carbon dioxide concentration, pH, moisture content, bulkweight and gross weight. Analyses were performed to determine the chemical composition of each waste material before and after composting. The number and types of chemical analyses made on each waste were varied due to the nature of the material. For example a greater number of measurements were required to characterize mixed refuse than were needed for newsprint. Overall, the chemical analysis used to typify each waste material included ash, volatile matter, crude fiber, lipids, bulkweight, ammonia and total nitrogen. Carbon dioxide concentration of the effluent gases were determined using an Aerograph gas chromatograph with a silica gel column.

When a liquid solution was required to perform an analysis on the solid waste a sample was prepared by placing one gram of mass in 50 milliliters of distilled water. Using a sample prepared in this manner pH was determined electronically using a pH meter. Moisture content of the mass was determined using 10 g samples. The mass was initially tared, then weighed after drying at 103 C for at least two hours. Bulkweight was measured by filling a container of known volume with material and weighing. The mass weight loss or utilization was calculated from a material balance of the gross weight in the composters measured at intervals during a run. A double beam balance accurate to ± 1 gram was used for this purpose.

Dried samples of waste were placed in a muffle furnace set at 600 C for 30 minutes to obtain the ash and volatile matter content. Crude fiber was measured by the method suggested by the APWA (8). A California buchner funnel was used in place of an alundum crucible. Lipids were extracted using petroleum ether or hexane and measured after two hours of refluxing in a soxlet apparatus. Total ammonia and nitrogen were determined by placing a known amount of sample in a Kjeldahl flask, adding water and using the Standard Methods procedure (9).

D. Specific Analyses

1. Concentration of leachate

Some of the difficulties that arise in composting include characterizing precisely the refuse and end product, and predicting the stabilization required for satisfactory treatment. These problems result because the composition of municipal wastes varies widely. Blending, on a large scale, to produce a homogeneous mixture, is hampered by the physical nature of solid wastes. The chemical oxygen demand (COD) of refuse which is related to the concentration of organic matter present has been suggested as a parameter for use in composting (8). In the present research, the COD of the leachate was used to indicate the degree of stabilization by composting.

Part of the organic matter present in mixed refuse is known to be or become soluble. Reports in the literature indicate the potential damage caused by leaching from sanitary landfills into underground water supplies (1). It was believed that if reliable and consistent COD values could be obtained for the soluble matter leached from refuse and composting mass, it would be possible to measure the effectiveness of the stabilization by comparing the initial and final COD of the soluble fractions.

The following procedure was used for determining the leachate COD of mixed refuse. Samples of the mixed refuse and product from the bench scale composters were taken for analysis. Four grams of moist mass (approximately 65 percent moisture) were weighed using a triple beam balance accurate to ± 0.1 gram. These samples were then diluted with 500 ml distilled water and mixed by means of a magnetic stirrer for one hour. After this time, the samples were filtered through a fine mesh stainless steel screen held on a California buchner funnel. The supernatant was centrifuged and the soluble fraction analyzed for COD by a rapid procedure (10).

A comparison of the COD concentration of this soluble matter before and after composting gave a measure of composting efficiency and the degree of refuse stabilization. Also, for experimental control it was possible to adjust the mass turnover time in the bench scale composter to study the rate of removal of the soluble fraction from the refuse.

2. Organic Carbon

Organic carbon of the mixed refuse and composted matter was determined using a Beckman Model 915 Total Organic Carbon analyzer. This technique provided rapid analysis of micro samples of refuse and composting material when in aqueous solution. Measurements of total carbon and inorganic carbon were made and their difference gave the organic carbon content. For determination of total and inorganic carbon,duplicate analyses were performed on each sample. The analyses were based on conversion of sample carbon into carbon dioxide for measurement by the Beckman non-dispersive infrared analyzer, Model 215A.

The samples required for the analysis were prepared using the crude fiber test which includes hydrolysis with acid and base. The analyses were performed on the residue remaining on the stainless steel screen after washing as described previously in "1. Concentration of Leachate." Hydrolysis consisted of two 20 minute mixing periods one in 100 ml of 0.1 N sodium hydroxide followed by one in 100 ml of 0.1 N sulfuric acid. The acidic and basic filtrates produced were recovered for organic carbon analysis. Each filtrate was neutralized, diluted with distilled water to a volume of 500 ml prior to injection into the carbon analyzer. The sum of the quantities of organic carbon measured were correlated to the weight loss of samples.

3. Volatile Acids

The volatile acid concentration of mixed refuse and composted mass was determined by the column partition method using silicic acid, as outlined in Standard Methods (9). Four gram samples, having approximately 65 percent moisture content, were placed in 100 ml of distilled water, and mixed for at least 20 minutes using a magnetic stirrer. The samples in solution were acidified to pH 2. Aliquots of 5 ml were added to the silicic acid column. Blank samples were also run as controls. The volatile acid concentration was determined by titration using 0.02 N sodium hydroxide in methanol.

E. Solid Waste Characteristics

Table 2 summarizes typical values obtained from the routine analyses performed on solid waste materials used as feed during the duration of the project.

While the solid waste characteristics of these substances are obvious from the table, the following comments on these parameters are necessary:

1. The crude fiber analysis has been used as a measure of the paper content in mixed refuse, yet the crude fiber content of newsprint was only 72 percent.
2. The average weight used in the bench scale composters was much lower for the newsprint medium because of the lower bulkweight of this material. It was found that the denser the waste material, the greater the amount that could be added to the composter without causing operational difficulties.
3. The high organic nitrogen content in the synthetic municipal refuse was attributable to a higher meat content.
4. Nutrient additions did not reflect attempts to optimize but merely to assure adequate levels of necessary constituents for composting without causing toxicity or limiting conditions.

TABLE 2

SOLID WASTE CHARACTERISTICS

	Newsprint	Altoona Compost	Municipal Refuse	Synthetic Municipal Refuse
Lipids (%)	0.5	-	3.0-9.0	9.7
Crude Fiber (%)	72.0	-	41-61	58.0
Ash (%)	0.5	9.2	4-20	11.0
Volatile Matter (%)	99.5	90.8	96-80	89.0
Crude Fiber/Ash	144	-	2-15	8.1
Bulkweight (pcf @65% Moisture)	5	-	10-15	9
Moisture (%)	5.0	38.6	30-60	47
Average Total Weight in Composters (g-wet)	1000-1400	1850-5000	3000	2000-3000
pH	4.2	7.3	5-8	7.0
Ammonia (mg/g) N as NH_3	0	1.8	0.5-1.4	0.7
Ammonia (mg/g) added	2.0	0	2.0	2.0
Organic Nitrogen (mg/g)	-	8.1	4.8-14	24.3
Total Nitrogen (mg/g)	-	9.9	7-17	27.0
Protein (.625 X Org.N) (%)	-	5.1	3.1-9.3	16.5
Phosphorus Added (mgP/g)	1.3	0	1.3	1.3
Potassium Added (mgP/g)	1.3	0	1.3	1.3

V RESULTS

A. Bench Scale Composters

A total of 24 composter runs were made using the battery of three bench scale composters. The substrates used during these investigations were newsprint, fresh and composted mixed refuse. A summary of the parameters studied is presented in Table 3. The study conditions used in each run are summarized in Table 2 of the Appendix. Each experimental run represents 10 to 30 days of operation at the desired conditions. The composting rate was estimated by measuring several parameters including (1) oxygen consumption and carbon dioxide production, (2) mass weight loss, and (3) reduction of volatile matter.

The information obtained during the bench scale composter runs is discussed fully in Section VI DISCUSSION, under the appropriate subheading for each environmental parameter studied. In the Discussion, the results of the continuously fed experiments have been correlated to the results of batch fed studies under the environmental conditions imposed. The results of the chemical analyses obtained for mixed refuse were more extensive and require some explanation. A typical summary of the chemical analyses and condition obtained during Composter Run 8 is presented in Table 4.

Composting mass was removed from each of the composters generally every 1 to 4 days and replaced with fresh refuse to simulate desired seed recycle ratios and mass turnover times.

Making the assumption that the composting mass was well mixed during treatment the mass turnover time for a run was approximated by dividing the mass exchange per day by the average mass in each composter:

$$\text{Mass turnover rate (days)} = \frac{\text{Average mass in composter (g)}}{\text{Mass exchanged daily (g/day)}} \quad (1)$$

The calculations performed to estimate the mass turnover rate, were based on the refuse added and composted material removed

TABLE 3

PARAMETERS STUDIED USING BENCH SCALE COMPOSTERS

Substrate	Newsprint Stabilized Mixed Refuse Fresh Mixed Refuse
Temperature (C)	35 to 70
Moisture (%)	60 to 70
Free Air Space (%)	25 to 35
pH	5.5 to 8.5
Buffer	Salts of Potassium Phosphate
Nitrogen Source	Ammonium Chloride
Mass Turnover Time (Days)	1.8 to 10.2
Seed Recycle (%)	0 to 75
Quantity of Material in Composter (gdm)	500 to 1450
Particle Size	One-quarter inch pieces
Oxygen Supply	Air, minimum 10% Residual Oxygen
Composter Rotation	Every 30 minutes to 6 hours

TABLE 4

SUMMARY OF DATA - COMPOSTER RUN 8

	Fresh Refuse	Composter		
		1	2	3
Lipids (%)	6.7	1.4	0.9	1.1
Crude Fiber (%)	47.5	52.0	58.3	56.3
Ash (%)	12.1	19.8	17.4	17.6
Volatile Matter (%)	87.8	80.2	82.6	82.4
Crude Fiber/Ash	3.9	2.6	3.4	3.2
Bulkweight(PCF@65% moisture)	12.7			
Temperature (°C)		50±2	65±2	65±2
Moisture % (wet)	49±1			
Moisture % Adjusted to	65±1	65±1	65±1	65±1
Free Air Space (%)	44±1			
Free Air Space Adjusted to(&)	32±1	32±1	32±1	32±1
Feed Interval (Days)		1	1	2
Average Total Weight (g)		973	1062	1058
Mass Detention Time (Days)		3.9→4.1	3.9→4.0	4.0→4.1
Seed Concentration (%)		73	75	50
pH	7.1±.2	7.8±.2	8.1±.2	8.2±.2
Ammonia(mg/g)N as NH_3	.3			
Ammonia(mg/g)Adjusted to	2.3	1.4	2.1	2.5
Organic Nitrogen (mg/g)	8.2	10.9	6.7	8.6
Total Nitrogen (mg/g)	10.5	12.3	8.8	11.1
Protein(6.25XOrg.N)%	5.1	6.9	4.2	5.4
Phosphorous added(%PasK_2HPO_4)	0.7			
Potassium added(%KasK_2HPO_4)	.17			
Max.Oxygen Consumption rate (mmole/day-g)		2.3	4.1	6.0
Aver.Oxygen Consumption Rate (mmole/day-gVM)		1.9	2.9	1.9
Aver. CO_2 Production (mmole/day-g)		1.9	2.4	1.9
Respiration Quotient		1.0	0.8	1.0
Oxygen Residual (%)		10.	10.	10.
Air Required(ft^3/day-LBVM)		8.5	13.5	9.1
Weight Loss (g/day)		38.	48.	46.
Weight Loss (%/day)		7.2	7.4	5.9
Reduction of Matter (%)(Ash)		38.6	30.1	31.0
Reduction of Matter (%)(Ash and Crude Fiber)		16.9	21.2	19.2

on a dry weight basis. Consideration was made in the latter calculations for the amount of mass converted to gaseous end products by biological means. Using this procedure a constant weight of mass was maintained in the composters during a run.

The seed recycle concentration was estimated by subtracting the percentage of the mass fed from the total in the composters:

$$\text{Seed recycle concentration (\%)} = 100 - \frac{\text{Mass fed daily X 100}}{\text{Average mass in composter}} \quad (2)$$

A sample calculation of the procedure to determine the mass turnover time and seed recycle concentration is presented in Table 3 of the Appendix. The seed recycle concentrations used during the runs were 25 to 75 percent. Mass turnover times of 1.8 to 10.2 days were studied.

The refuse was classified into five major fractions. Four of the fractions, including ash, crude fiber, protein and lipids were measured directly. The final component, called, "other volatile matter" was estimated as the remainder resulting after subtracting the sum of the weights of these four measured constituents from the total sample weight. "Other volatile matter" probably contains the simpler carbohydrates and organics present in the mixed refuse. The concentration of these five major components undergo significant changes during stabilization by composting. Due to the large reduction of volatile matter during composting the chemical analysis data of each component was adjusted to obtain more meaningful results. The amount of each component was estimated by correcting for the total matter remaining. Assuming the ash content in the initial refuse used represents fixed matter, the total matter remaining in the composted products were determined by the formula:

$$\text{TMR} = \frac{\text{AMR}}{\text{AC}} \text{ X } 100 \quad (3)$$

TMR = total matter remaining (%)
AMR = ash content of mixed refuse (%)
AC = ash content of composted product (%)

The amount of each component in the composted products, when adjusted for the total matter remaining provides a more accurate representation of the extent of stabilization by composting. A summary of the adjusted composition of mixed refuse after composting for Run 8 is presented in Table 4 of the Appendix.

Calculations were performed to determine the degree of stabilization of each component and the volatile matter reduction after composting. The results are summarized in Table 5. The volatile matter reduction was calculated using the formula suggested by Schulze (11):

$$VMR = \frac{AC-AMR}{AC\ (100 - AMR)} \times 10^4 \qquad (4)$$

where:

VMR = volatile matter reduction (%)
AC = ash of compost (%)
AMR = ash of mixed refuse (%)

The reduction in volatile matter for composting mixed refuse averaged about 50 percent for most runs. Reduction of various refuse components, as shown in Table 6, have been reported in previous composting investigations (12). The significant finding of the present research was the decrease in time required to obtain equivalent treatment. In the earlier studies, the volatile matter reduction was obtained for mass turnover times of 6 to 10 days after which stabilization was considered satisfactory (13). In the present studies, a similar degree of treatment was obtained with mass turnover times of as little as 2 days.

The most significant reductions of the refuse components were obtained in the "other volatile" and lipid fractions, averaging about 70 and 90 percent respectively. The protein

TABLE 5

STABILIZATION OF VARIOUS FRACTIONS OF REFUSE BY COMPOSTING

Composter Run	Composter	REDUCTION (%) Volatile Matter	Other Volatile	Lipids	Protein	Crude Fiber
7	1	45.7	73.0	59.6	41.3	30.7
	2	40.5	64.6	42.6	39.5	28.2
	3	50.5	89.7	47.5	56.5	30.2
8	1	44.2	57.5	87.2	17.3	33.1
	2	34.5	53.3	90.7	42.7	14.6
	3	35.6	52.9	88.7	27.2	18.5
9	1	54.2	75.5	73.5	14.4	40.0
	2	60.5	84.5	80.4	14.9	44.7
	3	47.2	64.5	78.6	15.9	33.9
10	1	54.2	74.7	41.9	41.2	40.0
	2	60.5	85.7	40.6	35.0	44.7
	3	47.2	62.7	31.3	52.8	34.2
12	1	72.2	73.5	89.6	66.8	69.5
	2	67.8	72.3	90.7	58.6	62.2
	3	70.5	78.0	89.1	27.5	66.5
13	1	41.2	58.7	44.1	30.1	32.7
	2	1.1	23.6	37.7	-6.3	-12.3
	3	23.6	41.7	47.5	27.1	12.2
14	1	68.8	77.5	82.0	33.0	63.4
	2	55.6	61.1	85.0	-25.4	51.8
	3	61.3	75.6	79.8	15.0	52.3
15	1	68.2	74.8	92.6	49.1	61.6
	2	55.6	62.8	88.1	2.0	50.1
	3	60.5	70.2	91.1	24.1	52.6

TABLE 5--cont'd

Composter Run	Composter	Reduction (%)				
		Volatile Matter	Other Volatile	Lipids	Protein	Crude Fiber
19	1	49.3	-56.0	76.7	83.5	43.9
	2	49.9	-17.6	85.1	97.3	44.8
	3	56.9	-32.0	89.8	85.5	50.7
20	1	79.0	79.0	91.2	72.5	77.8
	2	20.3	3.2	81.9	-4.7	20.0
	3	49.1	49.9	72.9	19.5	48.4
21	1	82.3	83.4	92.3	75.1	81.0
	2	69.7	65.1	83.8	75.5	68.6
	3	68.4	63.2	79.1	80.8	67.3
22	1	33.9	32.2	53.3	47.1	29.8
	2	33.9	70.4	24.4	15.7	22.5
	3	58.8	70.2	80.0	44.9	52.2
23	1	33.9	24.4	93.8	-13.7	33.3
	2	33.9	22.5	92.4	-4.9	33.3
	3	64.7	64.2	95.5	31.0	63.6
24	1	41.4	51.9	85.9	-1.1	34.6
	2	33.9	48.4	83.5	-4.9	24.1
	3	33.9	52.3	82.1	-26.5	25.3

TABLE 6

REMOVAL OF VARIOUS REFUSE COMPONENTS BY COMPOSTING

Refuse Components	Reduction (%)
Total Matter	27.9
Volatile Matter	31.5
Carbon	31.3
Lipids	76.7
Crude Fiber	7.0
Starch	88.4
Total Sugar	99.9
Protein	2.7

and crude fiber removal averaged about 30 and 40 percent respectively.

A material balance was made for total nitrogen in mixed refuse before and after composting. The nitrogen concentration was corrected for the total matter remaining. The sample results for Run 8, summarized in Table 7, show that nitrogen recovery in the compost was 59.1 to 72.4 percent. For all runs the total nitrogen recovered averaged closer to 80 percent. The initial ammonia concentration generally decreased after composting. A low recovery of total nitrogen in some cases was believed to indicate loss of ammonia during composting, significant concentrations of nitrite and nitrate, or experimental error in the chemical analysis of the refuse.

Material balances were made to compare the rate of stabilization of mixed refuse, predicted by each of the parameters used. The methods employed as indicators of biological stabilization were (1) rate of oxygen consumption or carbon dioxide production, (2) measured reduction in weight of mass and (3) reduction in total matter, assuming the ash content represents fixed matter. Unfortunately ash content within a single batch of refuse was not uniform. Thus, difficulty arose in obtaining a representative ash value for the batch. As an additional procedure the values for the total matter reduction were modified by assuming the fixed fraction of the refuse included both crude fiber and ash. This was done to minimize the error in the "total matter remaining calculations" using Equation (3), since small changes in the ash content of the refuse would cause significant error. Method 2 was chosen as the basis of comparison.

The method for calculating the percent mass reduction obtained by each of the four methods is presented in Table 1 of the Appendix. The results of these calculations are summarized in Table 8. The mass reduction for the remaining runs are presented in Table 5 of the Appendix. The agreement of mass

TABLE 7

NITROGEN RECOVERY FOR RUN 8

Material	Mixed Refuse	Composter 1	Composter 2	Composter 3
Matter Remaining	1.00	.614	.699	.690
Ammonia (mgN/g)	2.3	1.4	2.1	2.5
adjusted	2.3	.9	1.5	1.7
Organic (mgN/g)	8.2	10.9	6.7	8.6
adjusted	8.2	6.7	4.7	5.9
Total (mgN/g)	10.5	12.3	8.8	11.1
adjusted	10.5	7.6	6.2	7.6
Recovery	-	72.4	59.1	72.4

TABLE 8

COMPARISON OF VARIOUS METHODS FOR COMPUTING MASS REDUCTION

		Mass Reduction (%/day) Based on:				
Run	Composter	Meth. 1 Oxygen consump.	Meth. 2 meas. wt. loss	Meth.3 Vol. mat. red., ash fixed	Meth.4 Vol. mat. red. ash & crude fiber fixed	Aver. Meth. 1,2,4
8	1	4.1	3.91	10.50	4.6	4.2
	2	6.4	4.5	7.4	5.6	5.5
	3	4.2	4.3	7.8	4.9	4.5

reduction rates obtained by each method was generally satisfactory except for the high results predicted by Method 3.

Calculations were made for the mass reduction estimated using Method 3, assuming small changes in ash content of the refuse used for Run 8. The purpose was to demonstrate that a small error in the ash content of the refuse would cause a significant error in the predicted mass reduction rate. The results are presented in Table 9. The ash content of the refuse was assumed to be 12.0 ± 2.0 percent. The measured ash of the material in composters 1, 2 and 3 was 19.8, 17.4 and 17.6 percent, respectively. The mass reduction rates were 10.4 ± 3.0 and 7.4 ± 3.0 percent/day.

Since the refuse contained a significant amount of paper, the error in the mass reduction rate was less when the fixed fraction was adjusted to include the sum of the ash and crude fiber, as in Method 4. However, for Method 4 to be accurate experimentally the ratio of crude fiber and ash should remain constant before and after composting. The differences in the values of crude fiber/ash ratio reported in Table 4 indicate that the assumption of crude fiber remaining fixed was a good approximation for Run 8, but was poorer for many other runs.

TABLE 9

MASS REDUCTION RATE ERROR ANALYSIS

Assumed Ash of Mixed Refuse (%)	Mass Reduction Rate-Method 3 (%/day)		
	Composter 21	Composter 22	Composter 23
10.0	13.3	10.4	10.5
11.0	11.8	8.9	9.0
12.0	10.4	7.4	7.5
13.0	9.2	6.2	6.25
14.0	7.8	4.8	4.85

In the Discussion, Section VI, the composting rates under various environmental conditions was estimated by using rates of oxygen consumption and carbon dioxide production. In addition to being more reliable, the information was calculated from continuously monitored gas analyses.

B. Shake Flask Apparatus

The shake flask apparatus was used for a total of nine runs during this research. The first four runs were performed in the early part of the research and have been reported previously (2). The purpose of the earlier runs was to attempt to define the optimum conditions for cellulose degradation, using newsprint as the substrate. Table 10 summarizes the parameters studied during this period.

Four runs were performed for the purpose of finding the optimum temperature range for composting typical mixed refuse. Preliminary studies, pertaining to the effects of pH and seed concentration were also examined. The ninth and final study investigated the effect of temperature on the degradation rate of composted refuse. Table 11 contains an outline of the conditions studied for this phase of the research using mixed refuse. Table 12 summarizes the purpose and conclusions from the shake flasks studied. The results have been incorporated in Section VI DISCUSSION TEMPERATURE.

While the shake flasks were very useful in the study, the upkeep and data collection procedures were time consuming and cumbersome. The problems were most intensified during the mixed refuse studies, because of the high composting rates of this material. Round the clock analysis of the gas in the shake flasks was needed to prevent the occurrence of oxygen limiting conditions. Due to this difficulty the use of the shake flask was discontinued in the mixed refuse studies.

C. Warburg Respirometer

The Warburg Respirometer was used in place of the shake flasks. Table 13 gives an indication of the extent to which this apparatus was employed. The table summarizes a

TABLE 10

PARAMETERS STUDIED USING SHAKE FLASKS AND NEWSPRINT MEDIUM

Temperature (°C)	20,30,35,40,45,50,53
Moisture (%)	50,55,60,65,70
pH	5.0,6.0,7.0,8.0,9.0
Buffer	Sodium Bicarbonate, Potassium Phosphate
Nitrogen Sources	Ammonium chloride, Ammonium nitrate Sodium nitrate, Peptone
Carbon/Nitrogen Ratio	20/1
Seed Material	Effluent - bench scale composters Fairfield Engineering Co. digester Cultures - purified cellulolytic
Stimulants	Glucose, Nutrient broth, Yeast, Potassium phosphate, Various inocula
Particle Size	$\frac{1}{4}$ inch pieces - shredded
Oxygen Source	Air, Pure oxygen
Aeration	Daily, Twice daily
Agitation	None, Hourly, Bihourly
Quantity of Compost in Flasks (g)	20,40

TABLE 11

PARAMETERS STUDIED USING SHAKE FLASKS WITH MIXED REFUSE

RUN	# SAMPLES	TEMP. (%)	pH	SEED RECYCLE (%)	MOISTURE (%)
5	24	39-49	6.7-7.3	0 - 100	65
6	8	56-66	6.7-7.4	0,50	65
7	20	56-65	6.6-7.8	0 - 100	65
8	8	46-66	7.3	0,50	65
9	10	22-50	7.5	50	65

TABLE 12

PURPOSES AND CONCLUSIONS FOR SHAKE FLASKS STUDIES

RUN	SUBSTRATE	PURPOSE	CONCLUSION
1	Newsprint	Temperature, pH, N Source	Greatest CO_2 produced at 42-44C
2	Newsprint	CO_2 Production Due To Buffer	Sodium Bicarbonate Interference (discontinued as buffer)
3	Newsprint	Use of Phosphate Buffer	Good reproducibility CO_2 Production Useful Parameter in Measuring Biological Growth
4	Newsprint	Effects: Nutrient Broth, Glucose, Phosphate	Glucose & Nutrient Broth Stimulate Biological Activity
5	Mixed Refuse	Temperature Range 39-49C	Optimal Activity Above 49C
6	Mixed Refuse	Temperature Range 56-66C	Maximum Rates 58-61C
7	Mixed Refuse	Temperature Range 56-65C	Maximum Rate 56C
8	Mixed Refuse	Temperature Range 46-66C	Maximum Rate 58C
9	Stabilized Mixed Refuse	Temperature Range 22-50C	Maximum Rate 40C Results similar to Newsprint

TABLE 13

SUMMARY OF WARBURG RUNS

CONDITION CONSIDERED	RUNS	SAMPLES	OBSERVATIONS	REPORT REFERENCE
Statistical Analysis	1	16	16 identical flasks were analyzed for O_2 uptake rates and with data confidence limits, standard deviation, standard mean, etc. were determined	V-C
Free Air Space-Moisture Content	32-4	39	Runs were originally made to determine optimum moisture content-however the results were reanalyzed in the light of free air space when this was determined to be a more general parameter	VI-B
Effect of Seed Recycle	45-8	56	Flasks with varying amount of seed (0-100%) were run to determine optimum recycle ratios	VI-C
Effect of pH	29-10	32	Using seed acclimated to various pH's and seed adjusted to various pH (unacclimated) the general effect of pH was examined as well as determining the optimum pH value	VI-E
Nitrogen Concentration	11	16	Attempt to find optimum N concentration by using fixed seed to raw refuse ratio and increasing additions of N	VI-F
Phosphate Concentration	12	16	Attempt to find optimum P concentration by using fixed seed to raw refuse ratio and increasing additions of P	VI-F

TABLE 13--cont'd

CONDITION CONSIDERED	RUNS	SAMPLES	OBSERVATIONS	REPORT REFERENCE
Storage Time and Temperature	13	16	Examination of the possible interference caused by raw refuse being stored at different temperatures for varying lengths of time	VI-G
Paper Content	14	16	Effect of increasing paper concentration in raw refuse with a constant ratio of seed to raw refuse of 1:1	VI-H

total of 14 runs, involving some 207 samples, which were made to study significant environmental factors, including; free air space, moisture content, seed recycle, nutrients, pH, paper content, and refuse storage conditions. Included in Table 13 are reported references in this report where the results are discussed in detail.

Calculations were made to evaluate the flask stand for the Warburg Respirometer at the composting conditions used. This constant was obtained by evaluating the equation which follows:

$$k = \frac{(V_g \times 273/T) + (V_f \times d)}{P_o} \qquad (5)$$

where:

k = the flask constant (ml O_2/cm manometric fluid)
V_g = volume of the closed system (ml)
V_f = volume of sample in the flask (ml)
d = ml O_2/ml manometric fluid @20°C = 0.3251
T = °K of water bath
P_o = column of manometric fluid (cm) equivalent to 1 atm.

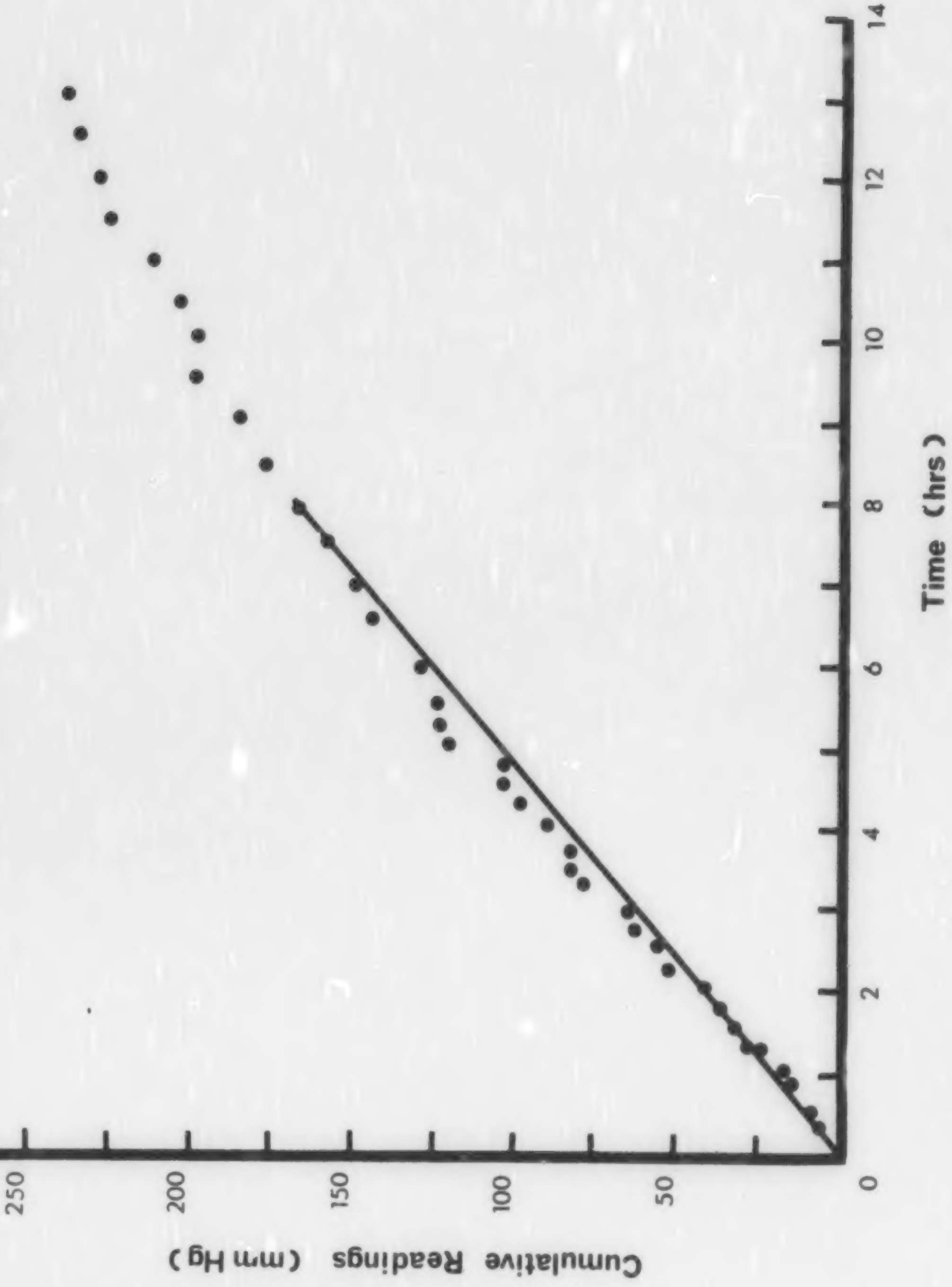
Substituting the proper values, the flask constant was determined to be 1.53 ml O_2/cm Hg at 59.6C and 1.58 ml O_2/cm Hg at 50.8C. Using the proper conversion factors, these values become 0.155 and 0.162 mg/O_2/gdm-manometer division. These values facilitated the computation of the composting rates since the oxygen uptake rates were obtained from a slope of a plot of cumulative manometer readings with time. An example of the information obtained in a Warburg study is presented in Figure 9.

The reliability which can be placed on the results from the Warburg studies was determined by a statistical analysis of the data, and a comparison of the Warburg results with those from the continuously run bench scale composters.

1) Statistics of Warburg Data

In order to determine the accuracy of the Warburg results a statistical analysis was performed on 15 duplicate samples. The Warburg apparatus was set up with 18 flasks,

Figure 9


TYPICAL EXAMPLE OF WARBURG DATA

including 2 thermobarometers, to correct for changes in atmospheric temperature and pressure, and 16 identical samples. A malfunction of a flask occurred during the run and was not included in the analyses.

From the oxygen consumption rates obtained for the 15 flasks, the mean was calculated to be 5.42 mg O_2/hr-gdm with a standard deviation of ± 0.457. As a check, the oxygen consumptions were plotted on probability paper, as shown in Figure 10, with the results that the mean was 5.48 with a standard deviation ± 0.44.

The values for the mean and standard deviation were used in calculations to determine the number of samples necessary to obtain 95 percent confidence. The results of these calculations show, for a 95 percent confidence, 11 replicate samples were required to obtain an answer within ± 5 percent of the mean, while only 3 replicate samples were needed to be ± 10 percent from the mean.

Typically, the Warburg runs were made with only duplicate samples, so that a wide range of conditions could be investigated at one time. Calculations were made to determine the confidence limits for two samples. To be within ± 5 and 10 percent of the mean, the confidence was 57.4 and 90.2 percent, respectively. For the not uncommon case of one of the duplicate flasks failing during a run (as happened during the Warburg run on the statistical analysis), confidence limits were also calculated based on only one result. To be within ± 5 and 10 percent of the mean, the confidence decreased to 44.6 and 75.7 percent, respectively.

2) Comparison: Warburg to Bench Scale Composter Data

While the statistical analysis shows that the results from the Warburg respirometer have a reasonable degree of reliability, more critical is the comparison of the results with the composting rates from the bench scale composters. As shown in Table 14, the ratio of Warburg to composter results range from 0.30 to 2.50. It is significant to note that the Warburg rates which represent only 8 to 10 hour average uptakes, were

Figure 10

PROBABILITY PLOT OF WARBURG STATISTICAL ANALYSIS

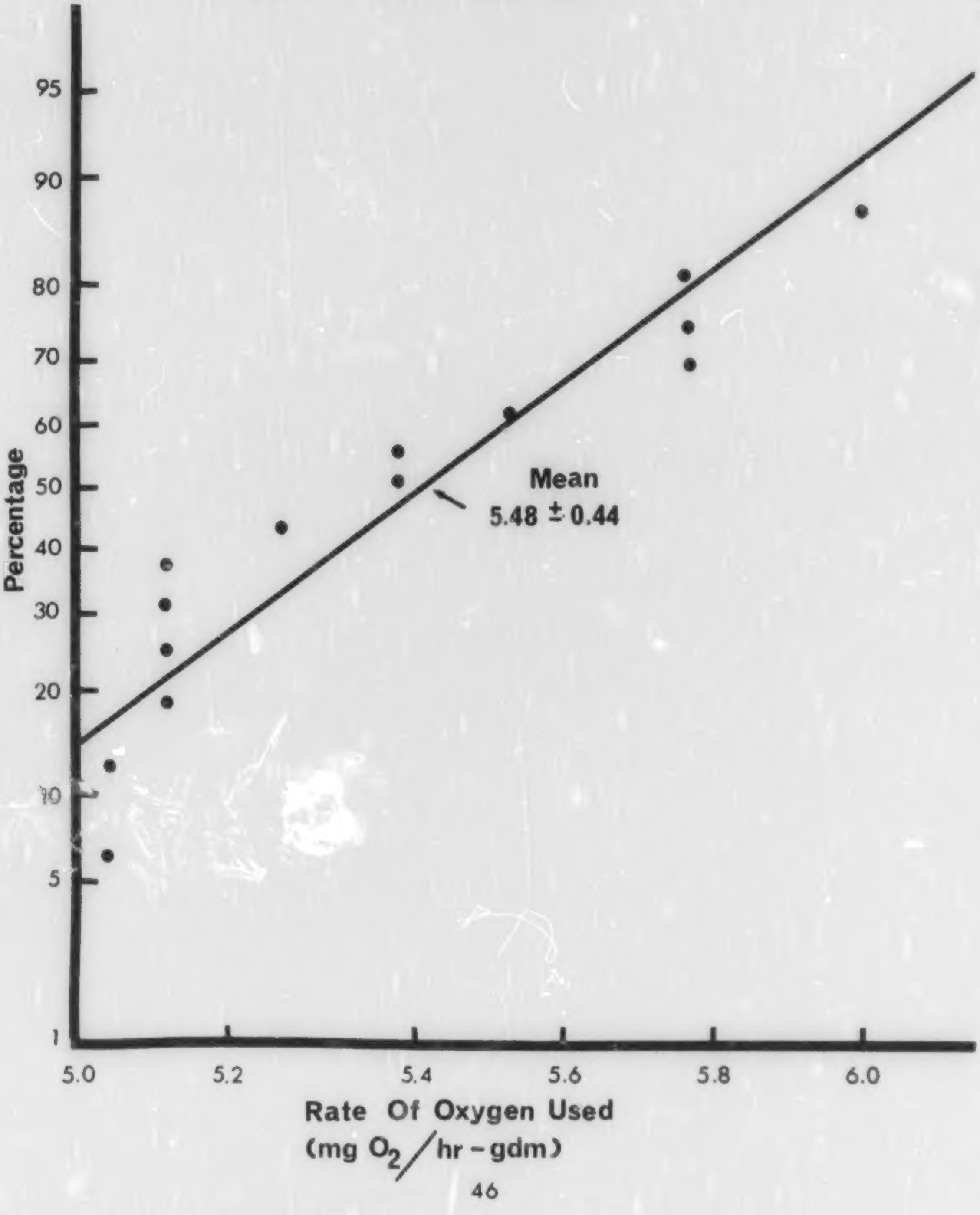


TABLE 14

COMPARISON OF COMPOSTING RATES FROM WARBURG AND BENCH SCALE COMPOSTERS

WARBURG		BENCH SCALE COMPOSTERS		
RUN NO.	RATE OF OXYGEN USED (mmole/day-gdm) (W)	RUN NO.	RATE OF OXYGEN USED mmole/day-gdm (C)	RATIO $\frac{W}{C}$
2	1.74	7	1.80	.98
3	1.63	7	5.5	.30
	3.02		2.8	1.08
5	3.38	8	1.6	2.10
6	4.85	10	3.4	1.42
9	2.20	10	3.4	.65
7	2.5	13	1.0	2.5
8	3.7	16	4.75	.77
10	1.26	21	3.0	.42
	1.85		2.0	.92
	2.75		5.0	.55
14	1.80	22	2.9	.62
11	3.3	23	4.3	.77
13	3.22	24	4.3	.75
13	2.19	24	2.9	.75

usually lower than the average rates from the bench scale composters. It was obvious that a reasonable conversion factor between the Warburg and bench scale composters cannot be obtained from this data. The assumption has been made that, for any particular run, a correlation factor existed. In this way general conclusions were drawn concerning the effect of a wide range of different environmental factors using the Warburg. The most promising results were used for the operation of bench scale composters for more significant application.

D. Miscellaneous

1) Organic Carbon

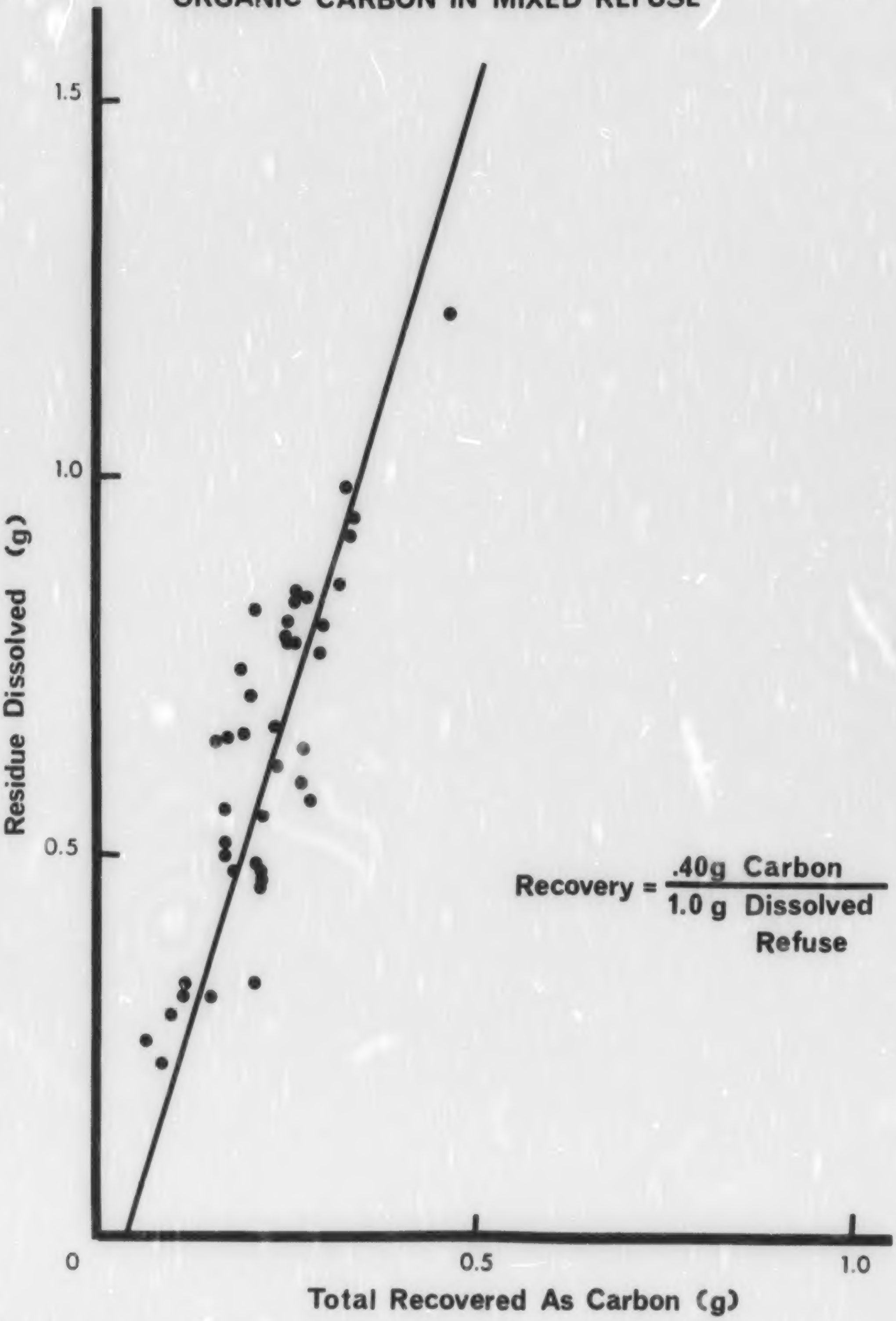
Soluble organics were obtained using the crude fiber procedure, in which samples were hydrolyzed in acid and base solutions as previously described. The organic carbon concentration in each solution was determined for samples of mixed refuse and composted material obtained from several bench scale composter runs. The total amount of organic carbon present in the acid and base solutions of each sample was related to the measured weight loss. Experimental results, presented in Figure 11, show that approximately 40 percent of a sample weight loss was recovered as organic carbon. This value agrees closely to the theoretical carbon fraction of carbohydrates assumed present in mixed refuse.

2) Volatile Acids

The removal of volatile acids from mixed refuse was investigated during Composter Run 15. The mixed refuse substrate had been collected approximately four days prior to use for the experiments and appeared to contain an unusually large vegetable waste fraction. Volatile acids in the refuse were measured and found to be approximately 50 mg/gdm or 5.0 percent. After treatment in the bench scale composters, operating at 56C, with turnover times of 1.8 to 2.4 days, the volatile acids decreased to neglegible concentrations. The composting rates did not appear to be affected by the relatively large concentration of volatile acids.

Figure 11

ORGANIC CARBON IN MIXED REFUSE



VI DISCUSSION

A. Temperature

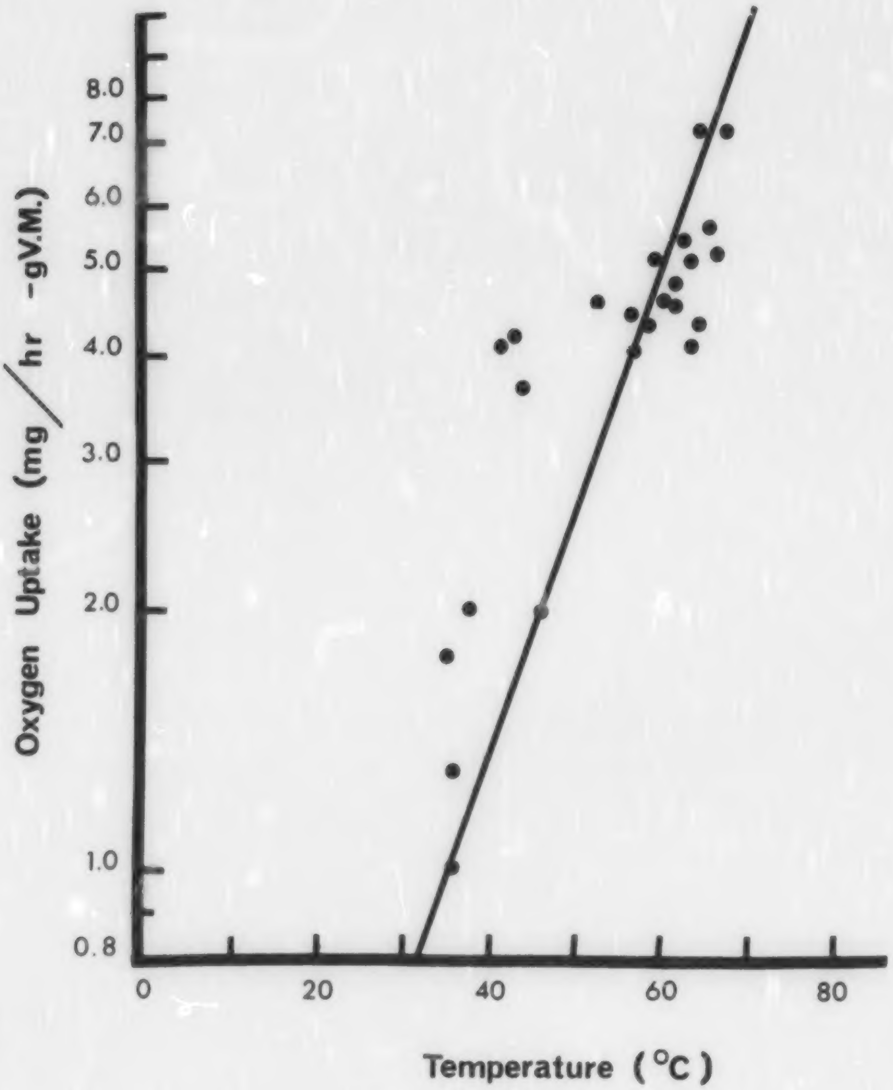
Temperature has frequently been used as a yardstick in composting to judge the efficiency and degree of stabilization of the treatment process. The generation of heat by microorganisms indigenous to municipal refuse results in the temperature of the composting mass to increase from ambient levels to as high as 70C. For windrow composting, which is a batch operation, temperatures suitable for thermophilic biota are obtained after a lag period. Maximum stabilization rates have been reported under thermophilic conditions (15). In a moist, well aerated windrow, the temperature will remain near the maximum until the readily degradable components of the waste are utilized. When the temperature of the windrow declines the waste is considered stabilized (16). Because of the initial lag period and poor control over the environmental conditions, windrow composting requires a long detention time for the stabilization of refuse.

Schulze (11) reported on continuously operated composting at thermophilic levels which eliminate the low temperature lag period characteristics of batch composting. Using a rotating drum pilot composter, Schulze maintained accelerated aerobic composting at temperatures between 53 and 70°C. Under these conditions the stabilization rate was maintained at a high level. On the basis of Schulze's research the feasibility of operating a continuous thermophilic composting process on a larger scale was demonstrated by the Fairfield Engineering Co. at Altoona, Pennsylvania (17).

Schulze found that the oxygen consumption rates obtained while composting municipal refuse, were highly dependent on temperature. These results, presented in Figure 12, indicate that the oxygen consumption rate increased with temperature to a maximum of 8 mg/hr-gVM, at 65 to 70C. Schulze did not investigate temperatures above this range however, experience has shown that

Figure 12

THE EFFECT OF TEMPERATURE ON OXYGEN UPTAKE IN COMPOSTING



the oxygen consumption rate would be expected to decrease at higher temperatures.

Since maximum stabilization rates of refuse appear to occur under thermophilic conditions and certain experimental gaps exist, a quantitative re-examination of the effect of temperature on composting was in order for high rate systems. This present evaluation emphasized the following points:

(1) As paper represents a major portion of today's municipal solid waste, the substrate used was deliberately proportioned with a significant amount of paper. Large quantities of a biologically resistant material such as cellulose, the major component of paper, most likely affect the conditions required to maintain an efficient composting operation. Unfortunately paper content was not considered critical in previous research and was a minor constituent of the refuse used.

(2) The average rates of degradation of the waste substrates, were determined after equilibrium conditions had been established in the composters. Instantaneous measurements of the composting rate, under non-equilibrium conditions were reported as results in previous studies by other researchers.

The objective of this phase of the research was to determine the temperature range required for maximum stabilization efficiency of municipal refuse having a high cellulose concentration. Composting experiments were performed at incubation temperatures between 22 and 70C. The materials used as feed during these experiments included; 1) newsprint, 2) stabilized municipal refuse obtained from the composting plant at Altoona, Pennsylvania and 3) typical mixed refuse containing 60 to 70 percent paper.

Initially the bench scale composters were used to produce seed material acclimated at the desired temperature study conditions. Mixtures of a fresh solid waste material and the corresponding seed were then used for batch fed experiments. The composting rates over wide ranges of temperatures were determined. The most promising results, provided by these preliminary studies, indicated the proper temperature range to be further examined in the bench scale composters as continuous systems.

(1) Newsprint

Carbon dioxide production rates presented in a previous progress report (2) have shown the effect of temperature between 30 to 48C on the degradation of a synthetic refuse containing primarily newsprint. Additional experiments extended the temperature range studied to 62C. The results are summarized in Table 15. The information presented was obtained from experiments using both the bench scale composters and the shake flasks. Seed material used in these studies was acclimated at the desired temperatures, at a pH of 7 and a moisture content of approximately 65 percent.

TABLE 15

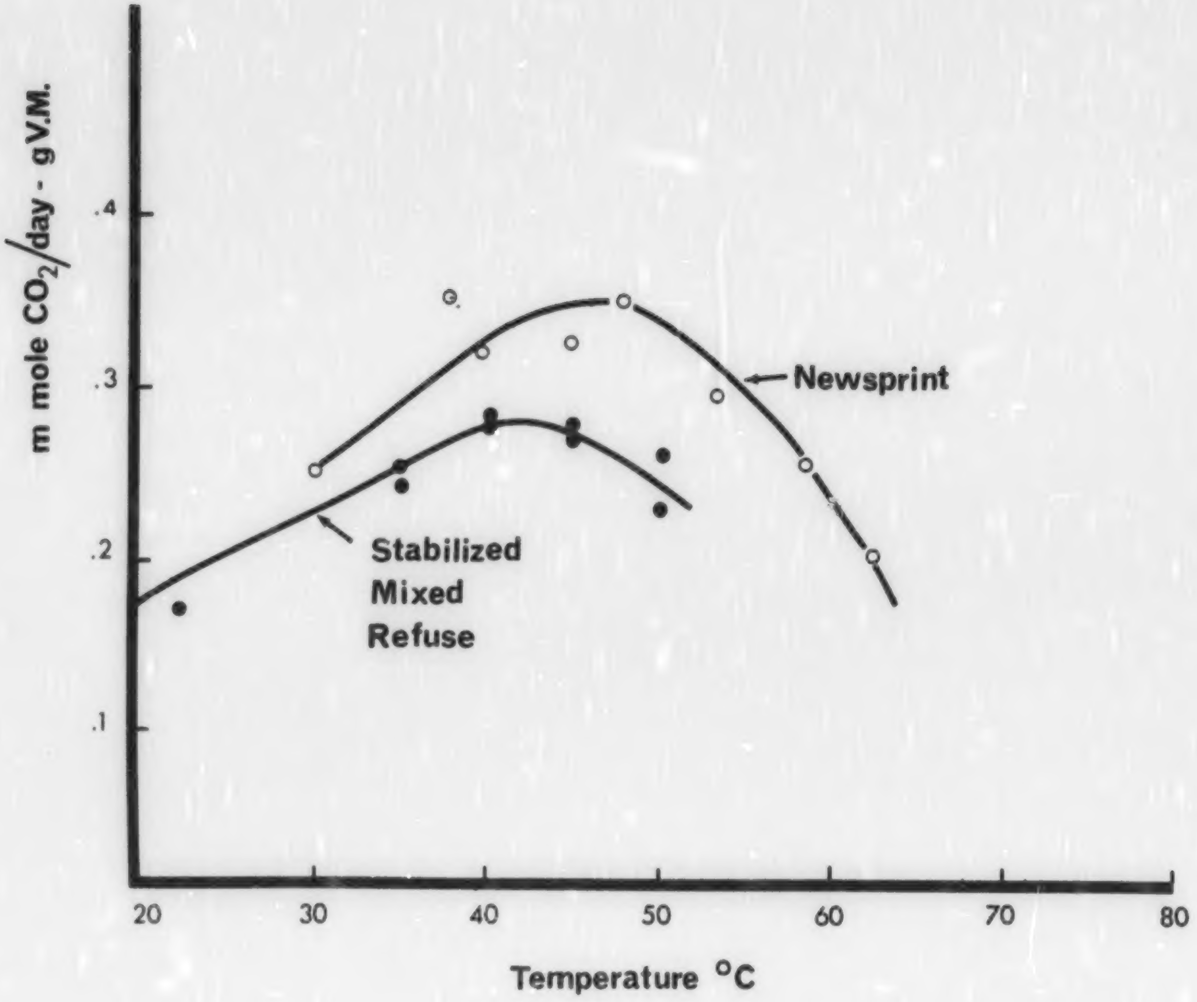
COMPOSTING RATES OBTAINED USING NEWSPRINT

Temp °C	mmole CO_2/ day-gdm	mmole CO_2/ day-gVM
30	.25	.26
37	.35	.37
40	.25	.26
	.30	.32
45	.30	.32
48	.33	.35
53	.30	.30
58	.25	.26
62	.20	.21

The effect of temperature on the rate of composting newsprint is presented in Figure 13. The results show that the carbon dioxide production rate increased from 0.26 mmole/day-gVM at 30C to a maximum rate of 0.35 mmole/day-gVM at 48C. Decreased biological activity was observed as temperatures were increased to 62C. This confirms reports in the literature (18) that a predominate number of species of microorganisms capable of utilizing cellulose in nature operate most efficiently within the 45 to 50C range.

Figure 13

CARBON DIOXIDE PRODUCTION VS. TEMPERATURE FOR CELLULOLYTIC MATERIALS



(2) Stabilized Municipal Refuse

A sample of composted municipal refuse was obtained from Altoona, Pennsylvania. Allowing 7 days time for treatment at the plant and transit to the laboratory, the material had been stabilizing for approximately two weeks, when used in the composting experiments. Thirty grams of sample were placed in each of ten shake flasks after the moisture content was adjusted to 65 percent. The pH of the samples was approximately 7.5. Duplicate shake flasks were incubated at temperatures between 22 and 50C, and carbon dioxide production rates were measured daily for 18 days.

The average composting rates obtained for the mixed refuse are summarized in Table 16, and were included in Figure 13. The results indicate that the carbon dioxide production rate reached a maximum of 0.28 mmole/day-gVM at 40C. The magnitude of the stabilization rates obtained were similar to those previously found for newsprint. This indicates that the composting of the Altoona refuse was essentially complete after 14 days when it was obtained for the experiments. Most of the easily biologically utilized materials were already stabilized. In effect residual cellulose and other resistant materials in the refuse continued to be slowly degraded during the shake flask studies.

TABLE 16

COMPOSTING RATES OBTAINED
USING STABILIZED MIXED REFUSE

Temp °C	mmole/ day-gdm	mmole/ day-gVM
22	.155	.170
22	.240	.263
35	.220	.241
35	.230	.252
40	.25	.274
40	.255	.280
45	.245	.269
45	.25	.274
50	.205	.225
50	.235	.257

(3) Typical Mixed Refuse

Samples containing approximately 50 pounds of ground and shredded mixed refuse were collected every other week from an urban area near Philadelphia, Pennsylvania and used as feed during one phase of the composting experiments. Several different batches were used to obtain the information presented. Prior to grinding, glass and metallic components were removed. The results of chemical analyses, presented in Table 17, characterize the batches of mixed refuse used. The variability of the constituents was significant. Crude fiber, was found to range from 41.8 to 53.9 percent and volatile matter varied from 84.5 to 89.3 percent. The lipid and protein fractions averaged 6.0 to 7.0 percent, respectively.

TABLE 17

CHEMICAL ANALYSIS OF MIXED REFUSE

	Run 6	Run 7	Run 8	Run 9
Moisture	39	60	49	56
Free Air Space (%)	55	35	44	38
pH	5.2	6.0	7.1	6.3
Lipids (%)	6.2	6.9	6.7	4.5
Crude Fiber (%)	53.9	47.7	47.5	41.8
Ash (%)	10.7	12.8	12.1	15.5
Volatile Matter (%)	89.3	87.2	87.9	84.5
Ammonia (mgN/gdm)	.8	.1	.3	.2
Organic Nitrogen (mgN/gdm)	11.9	13.9	8.2	8.0
Protein (.625xN) (%)	9.2	8.7	5.1	5.0
Bulkweight lbs/cuft (moisture 65%)	-	-	12.7	20

Experiments using this mixed refuse were performed in both the shake flasks and the bench scale composters. Temperatures studied extended from 35 to 70C. For all the experiments, only seed material acclimated to the desired temperature conditions was used. For the typical refuse used, the free air space (Figure 18) was close to 30 percent when the moisture content was 60 to 65 percent. The pH of the composting mass during the studies was approximately 8. Carbon dioxide production rates, obtained from shake flasks are summarized in Table 18 and Figure 14 while the results using mixed refuse in the bench scale composters are tabulated in Table 19 and Figure 15. In both cases, the composting rates increased with temperature reaching maximum values near 60C. A decrease in the composting rate was observed at higher temperatures.

TABLE 18

COMPOSTING RATES
USING MIXED REFUSE
IN SHAKE FLASKS

	Peak mmole CO_2/day	
Temp (C)	Per gdm	Per gVM
35	.9	1.1
40	1.8	2.2
	1.85	2.3
	1.9	2.3
45	2.15	2.7
	2.38	2.9
	2.40	3.0
47	2.20	2.7
	2.60	3.2
50	1.70	2.1
	2.9	3.6
	2.95	3.7
54	3.45	4.3
56	3.40	4.2
	3.35	4.1
58	2.65	3.3
63	3.6	4.4
	4.8	5.9
64	1.65	2.0
65	3.0	3.7
66	1.6	2.0

Figure 14
CARBON DIOXIDE PRODUCTION RATE vs TEMPERATURE FOR CELLULOLYTIC MATERIALS

Result Comparison

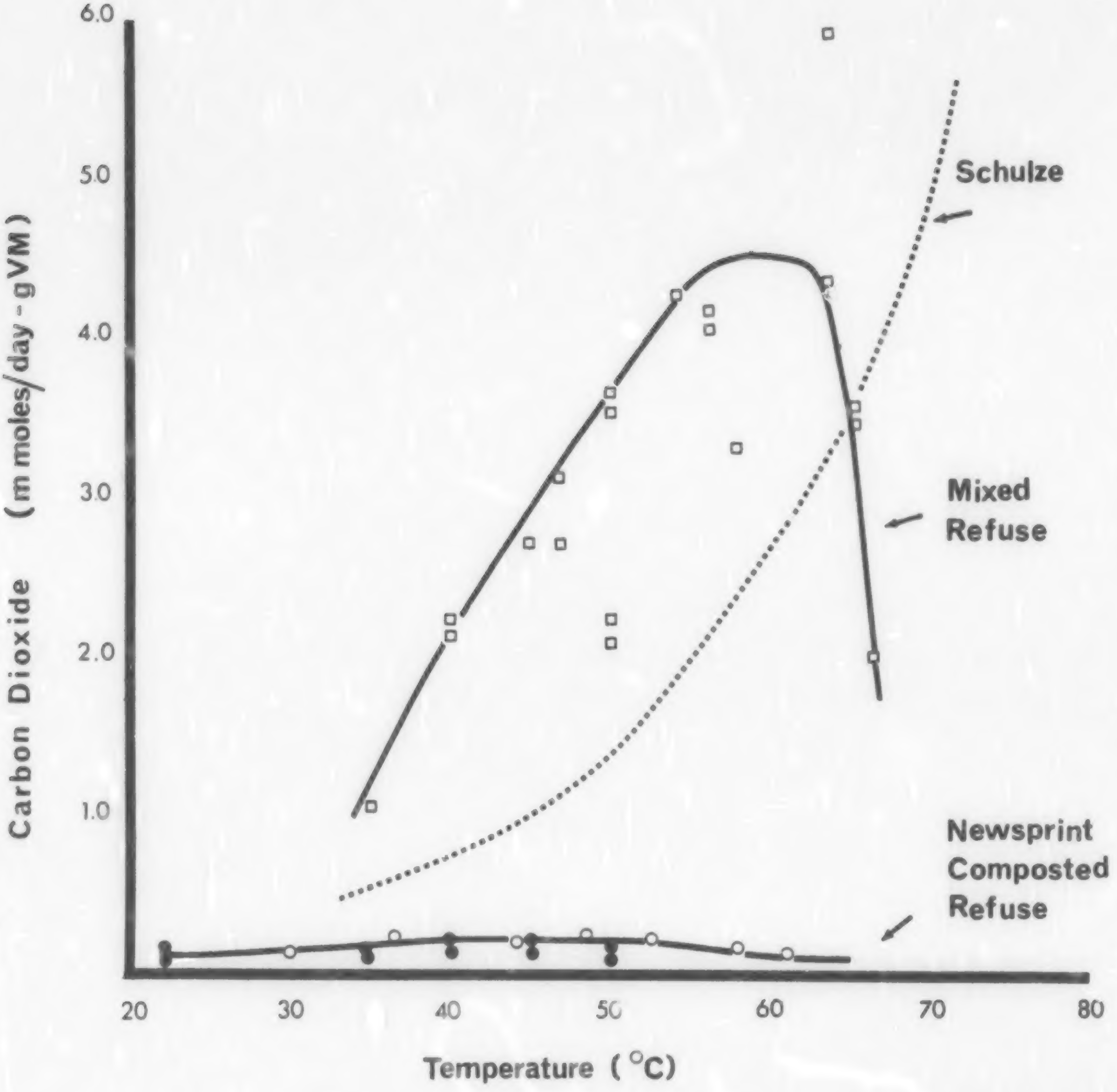


Figure 15

EFFECT OF TEMPERATURE ON OXYGEN CONSUMPTION RATE FOR MIXED REFUSE

Based On Average Oxygen Consumed
Using Continuously Fed
Composters

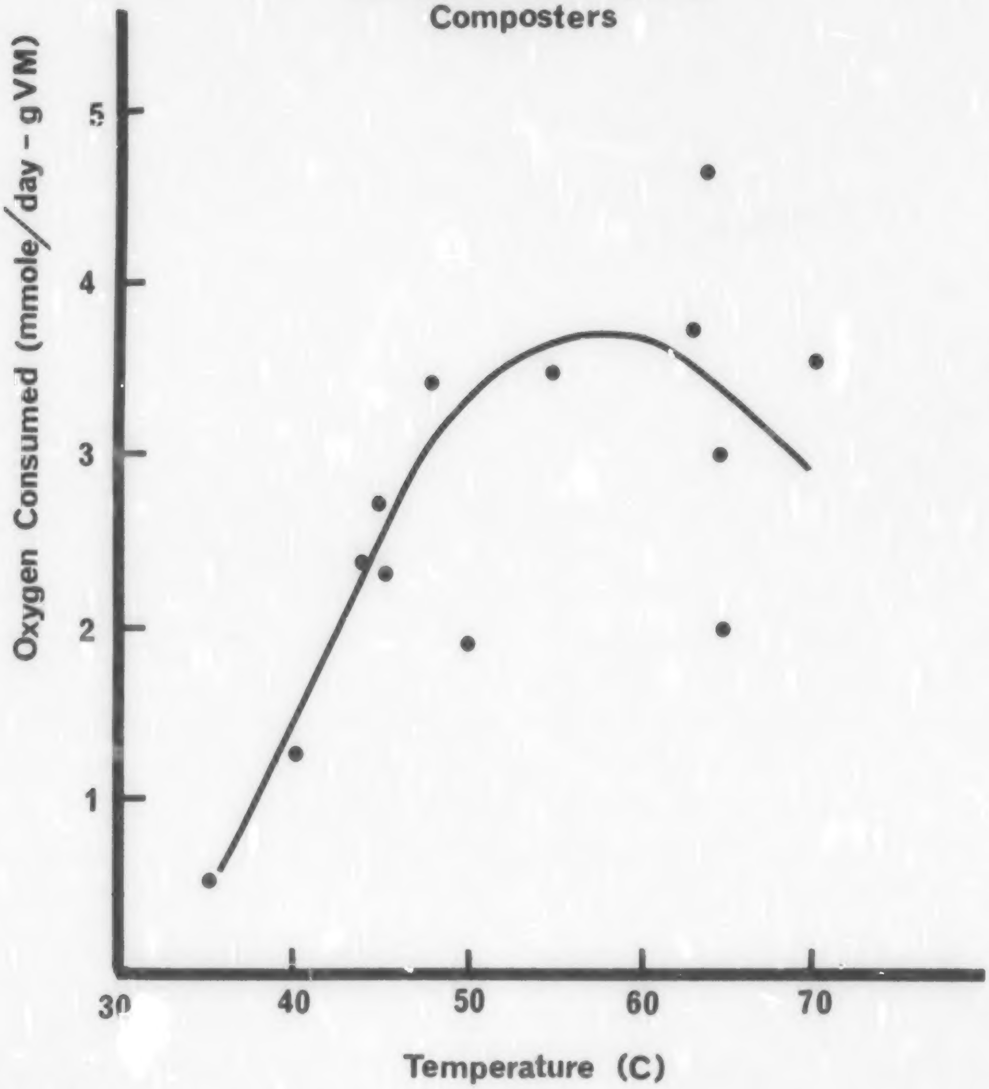


TABLE 19
COMPOSTING RATES USING MIXED REFUSE IN BENCH SCALE COMPOSTERS

	Ave. mmole O_2/day	
Temp (C)	Per gdm	Per gVM
35	0.4	0.5
40	1.0	1.25
44	1.75	2.35
45	1.8	2.3
45	2.0	2.7
48	2.5	3.35
50	1.5	1.88
55	2.5	3.5
63	2.5	3.7
64	3.4	4.6
65	2.4	2.9
65	1.6	1.95
70	2.8	3.5

The composting rates obtained for the materials previously reported in Figure 13 are included in Figure 14 along with the results reported by Schulze (11). At 60C the optimum temperature conditions for this investigation, the composting rate obtained for mixed refuse was 61 percent greater than Schulze's reported value. Degradation rates of newsprint and stabilized municipal refuse were approximately 10 percent of those found for mixed refuse. Schulze reported maximum results occurred at temperatures close to 70C. The difference in the optimum temperature was possibly the results of the following:

a) The composting rates reported by Schulze were not obtained at equilibrium operating conditions. After preliminary results were obtained in batch fed experiments, the bulk data was collected during a single run by measuring instanteous temperatures and oxygen consumption rates over a 3-day period. These measurements varied significantly during a relatively short period of time. In contrast to Shulze's work the results of the present experiments were obtained when the biological process was operating at close to continuous equilibrium conditions. The carbon dioxide production rates presented in Figure 14 represent the peak values obtained in the shake flasks using 50 percent acclimated seed material. The oxygen consumption rates presented in Figure 15 for the bench scale composters represent the average results obtained for 10 to 16 days at constant conditions. The optimum composting rate obtained for mixed refuse under these conditions was between 3.7 and 4.5 mmole/day gVM.

b) Schulze's research was limited to refuse containing small amounts of paper while the refuse used in the present study contained 60 to 70 percent paper and was more typical of solid waste of American cities.

4) Mathematical Data Fitting

In order to determine if the effect of temperature on the composting rate of each of the materials was comparable, mathematical expressions were developed. The equation was assumed to approximate the form:

$$y = ax^2 + bx + c \quad (6)$$

where:

y = composting rate expressed as (mmole O_2 or CO_2/day gVM)
x = temperature (C)
a, b, c = constants

The coefficients were ennumerated after differentiating equation (6) obtaining:

$$\frac{dy}{dx} = 2\,ax + b \quad (7)$$

When the data yields a straight line, the slope is "2a" and the "y" intercept is equal to "b". Coefficient "c" is then evaluated from Equation (6) using coefficients "a" and "b" with known values of "x" and "y".

The values of dy/dx in Equation (7) were calculated from the curves presented in Figure 13 and used to evaluate the coefficients for newsprint and stabilized municipal refuse, as shown in Figure 16. Similar information was generated from Figures 14 and 15 to determine the value of the coefficients to describe the composting rate of mixed refuse shown in Figure 17. The data for each waste was represented by the following equations:

1) Newsprint

$$y = -.0011x^2 + .106x - 2.18 \qquad (8)$$

2) Stabilized Mixed Refuse

$$y = -.0010x^2 + .076x - 1.19 \qquad (9)$$

3) Mixed Refuse (Shake Flasks)

$$y = - .029x^2 + 3.42x - 88.45 \qquad (10)$$

4) Mixed Refuse (Bench Scale composters)

$$y = -.029x^2 + 3.42x - 89.15 \qquad (11)$$

The small numerical values of the coefficients "a" and "b" were similar for the newsprint and stabilized mixed refuse and indicate the biologically resistant nature of these materials. The larger values of the coefficients "a" and "b" using mixed refuse indicate a far greater rate of stabilization.

The values of the coefficient obtained using mixed refuse in the shake flasks and bench scale composters show that the results were comparable.

The optimum temperature requirement found for each material was determined by differentiating equations (8), (9), (10), and (11). The results summarized in Table 20 indicate temperatures of 40 to 48C give maximum composting rates for newsprint and stabilized mixed refuse. Maximum composting rates for fresh mixed refuse were obtained at 50C. Ninety-five percent of the maximum composting rate was obtained when the temperature was maintained within 5 to 10C from the optimum value for each of the materials studied.

5) Summary

The use of thermophilic temperature conditions for composting organic solid wastes is an established practice. However, only limited information has been available concerning

Figure 16

RATE OF CHANGE OF CARBON DIOXIDE PRODUCTION VS. TEMPERATURE USING CELLULOLYTIC MATERIAL

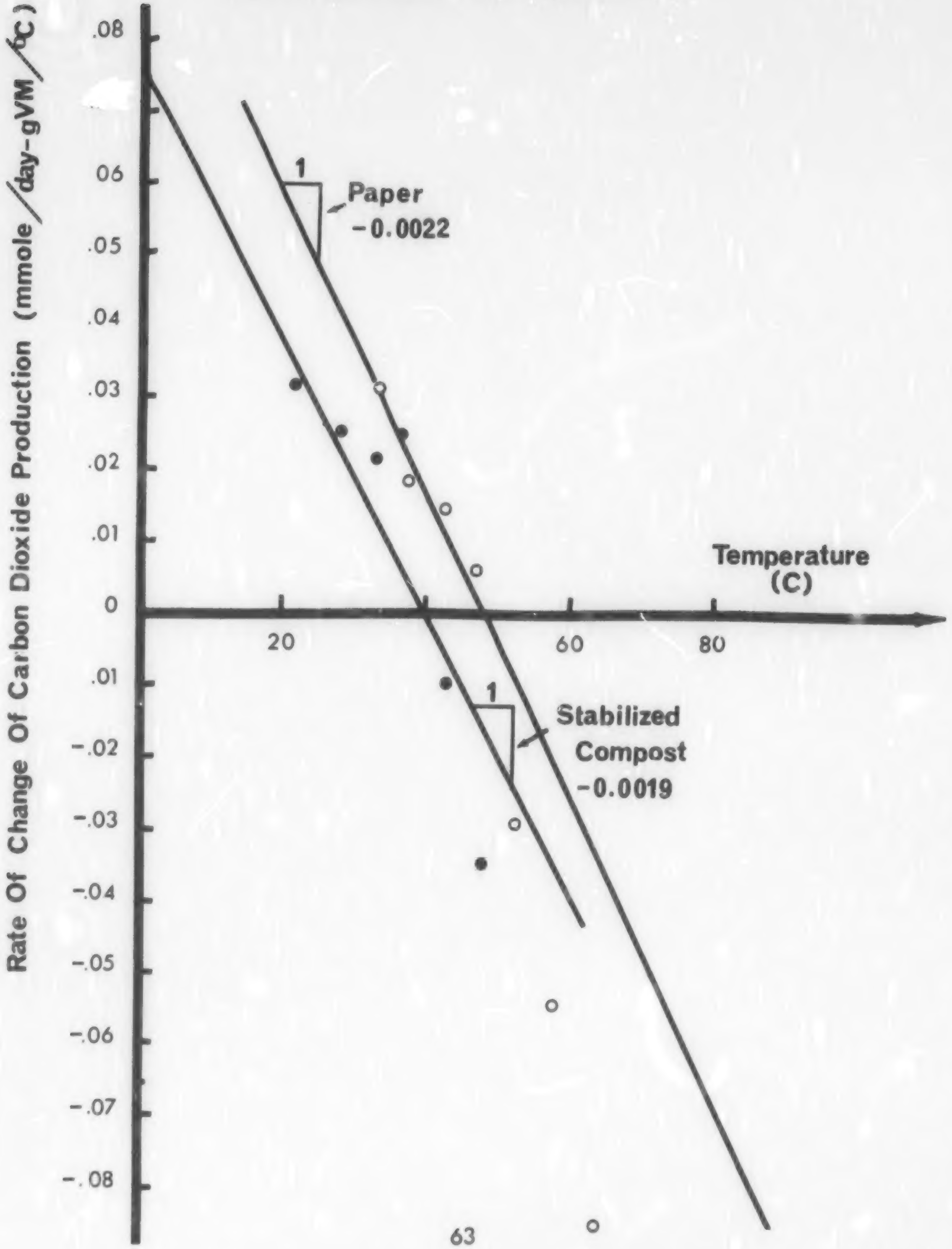
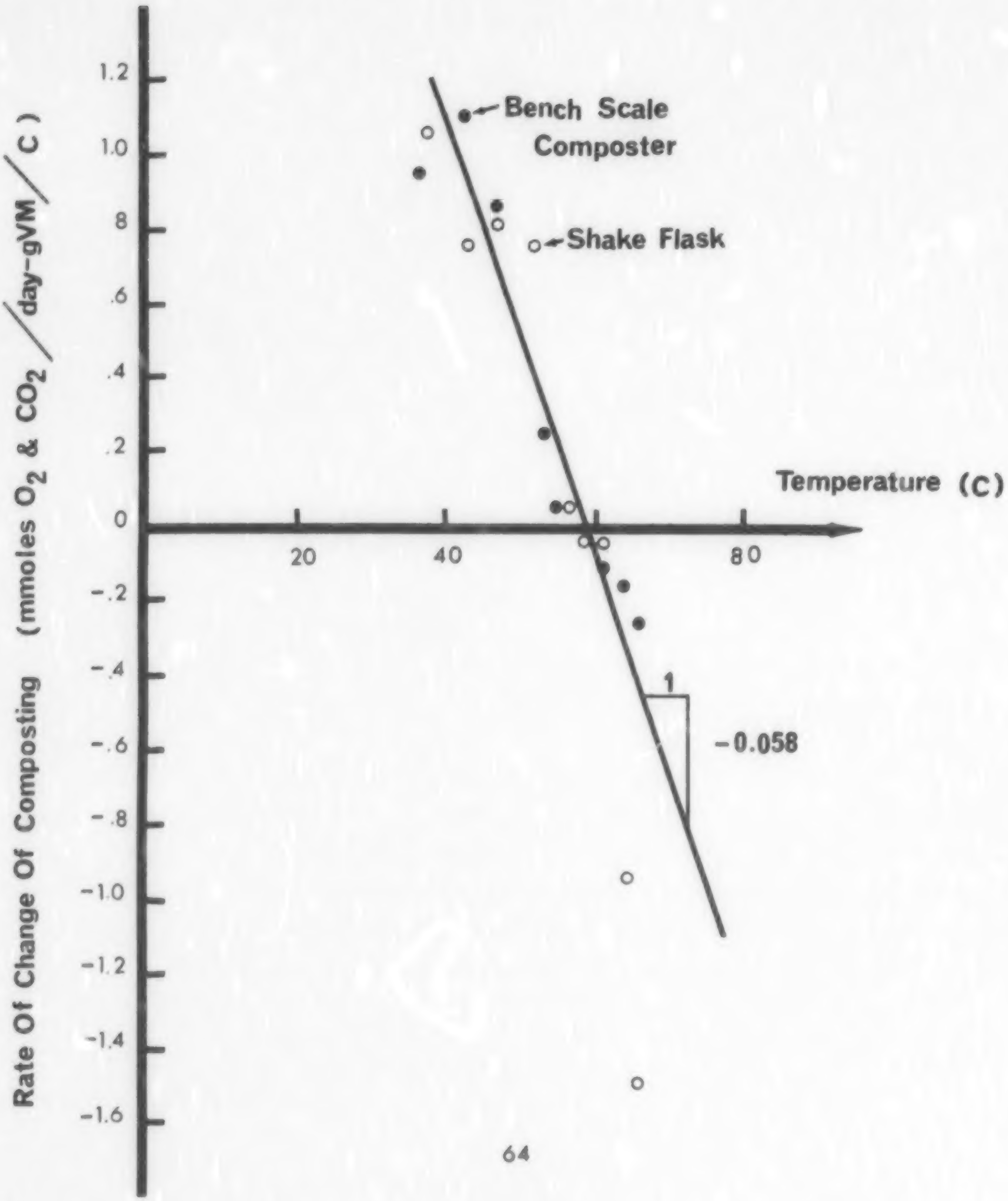


Figure 17

RATE OF CHANGE OF COMPOSTING VS. TEMPERATURE USING MIXED REFUSE



the composting rate of mixed refuse at various temperatures. Further knowledge of the environmental conditions required for improved and more rapid degradation of biologically resistant materials such as cellulose using composting has also been lacking. The composting rates at each temperature obtained in the present investigation are significantly greater than the "accelerated" rates that have been previously reported in the literature.

TABLE 20

TEMPERATURE CONDITIONS FOR OPTIMUM
COMPOSTING OF CELLULOLYTIC SOLID WASTES

Material	Composting Rate mmole/day-g VM	Optimum Temperature (C)
Newsprint	.35	48
Stabilized Municipal Refuse	.28	40
Mixed Refuse	3.7-4.5	59

More efficient composting rates obtained in this investigation were the result of the following: a) temperature was controlled within ± 2C of the desired level; b) all of the composting rates were obtained with samples containing seed acclimated to within 5C of the desired study temperature; c) environmental factors including pH, moisture and free air space were controlled within narrow limits; and d) aerobic conditions were maintained at all times.

This investigation has shown that a high level of environmental control is desirable for improved composting efficiency. The necessity of process design and control in biological waste treatment has long been recognized by engineers and plant operators. The application of similar considerations to solid waste treatment using composting has been lacking and has been partially responsible for many of the past failures reported.

B. Moisture Content and Free Air Space

The rate of stabilization of organic material by composting microorganisms is highly dependent upon the environmental factors to which the flora are subjected. Generally, modern mechanical composting processes attempt to create a suitable environment for thermophilic facultative aerobic microorganisms (19). Criteria for successful composting include; 1) proper temperature and pH, 2) adequate aeration and mixing of organic solids, 3) proper moisture content, 4) suitable structure and particle size, and 5) proper concentration of nutrients (1,2).

Of the many environmental parameters, moisture content has been referred to as "the most important criterion for optimum composting"(20). Sufficient moisture in the waste material is required for maximum efficiency of microbial stabilization. When the moisture content is excessive, the interstices within the organic mass become filled with water and aeration is restricted. As the oxygen concentration is depleted within the material an anaerobic condition develops which results in odors and a significant decrease in the rate of decomposition. (If oxygen were not limiting under such conditions, the biological growth rate would most likely be greater).

Optimum moisture requirements for successful composting of a wide variety of organic wastes are summarized in Table 21. Overall the suitable moisture contents reported for organic wastes range from 25 to 80 percent. This wide range of "optimum" moisture content indicates that a more fundamental and inclusive parameter is needed for understanding the physical and biological interactions controlling composting. It seems fairly obvious that additional factors must affect the optimum stabilization requirements of the various organic waste materials to result in this wide spread in moisture content.

Wiley (29) indicated that the optimum moisture for composting garbage and refuse depends on the composition of the mixture and a summary of information reported is given in Table 22. Wiley suggested the concept of "effective liquid content" as a more valid parameter. The term "liquid content" includes water and all other free flowing fluids such as lipids,

TABLE 21

REPORTED OPTIMUM MOISTURE CONTENTS

Moisture Content(%)	Material Composition	Geographical Location & Date	Reference
45-50	Nightsoil	India (1956)	(16)
75-80	Farmyard Manure in Straw	USA (1939)	(16)
60-70	Municipal Refuse and Sludge - Some Paper removed	Texas (1967)	(21)
47-60	Municipal Refuse (50% Paper)	Altoona, Pa. (1965)	(22)
50-55	Refuse & 40% Nightsoil (25% Paper)	Japan (1961)	(23)
60-65	Municipal Refuse (53% Paper)	Savannah, Ga. (1955)	(24)
57-58	Municipal Refuse (33% Paper)	East Lansing, Mich. (1956)	(25)
50-60	Synthetic Refuse (11-14% Paper)	East Lansing, Mich. (1961)	(12)
25 is sufficient	Poultry Manure	USA (1963)	(20)
50-60	Refuse and Sludge	Germany (1962)	(26)
60-70	Fruit wastes and rice hulls or sawdust	California (1968)	(27)
50-56	Beef feedlot waste	Texas (1969)	(28)
65	Synthetic Refuse (100% Paper)	Manhattan College (1968)	(2)

TABLE 22

OPTIMUM MOISTURE CONTENT OF HIGH-RATE MECHANICAL COMPOSTING (29)

Location	Material Composted	Moisture Content %		Effective Liquid Content %
		Desirable	Optimum	
Savannah, Georgia	Municipal Refuse some Paper Removed	55-69	60-65	68.1
East Lansing Michigan	Wrapped Municipal Refuse	55-60	57-58	67.5
Kobe, Japan	Refuse Contains 25% soil	Unknown 60-70 is too high	about 50-55	70.1

but not gases, at temperatures reached during thermophilic composting. Using "effective liquid content" as a parameter, the data for optimum composting of municipal refuse gives better agreement among the various researchers as indicated in Table 22. However, this concept alone does not totally explain the significantly different moisture requirements of other organic wastes, including poultry manure, barnyard manure with straw, and night-soil.

Another factor that affects the moisture requirements of organic waste is particle size. Grinding the material improves the rate of decomposition. However, aeration is adversely affected by finely ground material (8). For example, the moisture content of a compact organic waste, such as poultry manure, must be low to compensate for the poor aeration characteristics of this type of waste. On the other hand, a higher moisture content is permissible for a porous mixture of straw and manure.

A parameter that has been suggested to provide a clearer insight into the mechanisms of composting which is related to the moisture content and the physical structure of the organic waste is called "free air space" (FAS) (11). The "free air space" concept has been adapted from soil science and relates the specific gravity (Sg), bulk weight (wB) and dry mass (dm = 1-moisture fraction) of a waste to the air filled voids within the material. The working equation to determine the percent free air space for any given waste is:

$$FAS = 100\,(1-[wBxdm/Sg])xdm \quad (12)$$

The derivation of this equation is presented in Appendix Table 6.

Equation 12 was used to determine the relationship of free air space and moisture content for several organic wastes presented in Table 21 and the mixed refuse used in the present investigation. The results of these calculations, along with the moisture contents reported optimum for each waste are presented in Figure 18. The results show that as paper content increases, the most suitable moisture content for composting an organic waste increases. The moisture requirement for composting increased from 53 percent for beef feed lot wastes to 65 percent for wastes containing significant quantities of paper. The corresponding free air space remained constant at 32 to 36 percent.

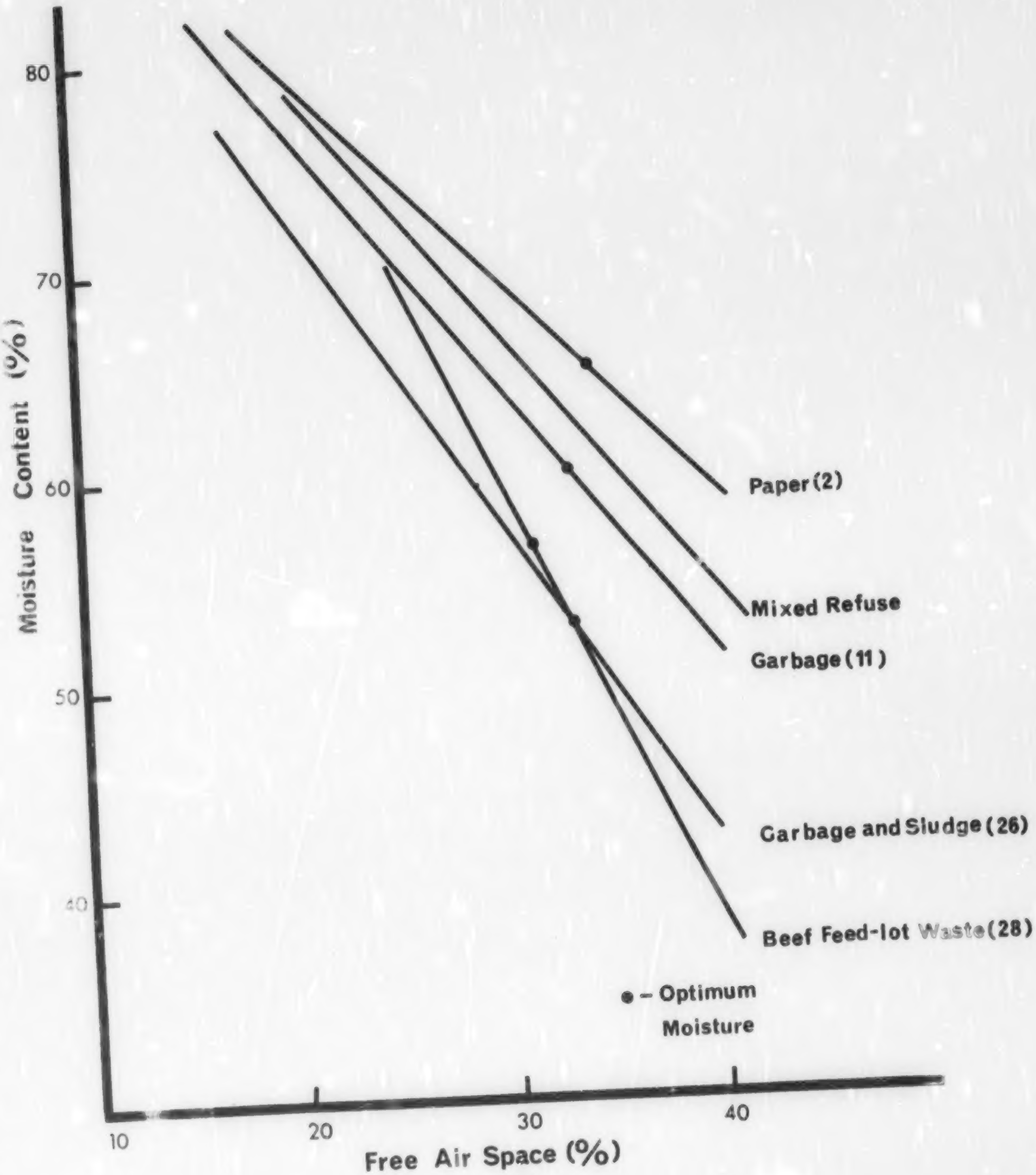
Bloodgood, as reported by Schulze (11), found that over the period 1950 to 1960, the density of mixed refuse in several American cities decreased from 40 lbs/cu ft to as little as 6 lbs/cu ft due to the increase in paper content. This decrease in the bulk weight of refuse has the effect of significantly increasing the free air space. Therefore, if a uniform free air space requirement for organic wastes exists, as indicated in Figure 18, the moisture requirement for composting mixed refuse may be significantly affected by paper content.

This phase of the research was undertaken to investigate the relationship of free air space and the rate of composting mixed refuse containing 60 to 70 percent paper. Oxygen uptake, which is related to the composting rate, was measured for samples containing free air space values of 11 to 44 percent to determine the free air space requirement for maximum aerobic stabilization.

The Warburg Respirometer was used to determine the total oxygen consumption and oxygen consumption rates for each of the samples in Runs 2, 3, and 4. Samples contained, on a dry

Figure 18

MOISTURE CONTENT VS. FREE AIR SPACE FOR ORGANIC SOLID WASTES



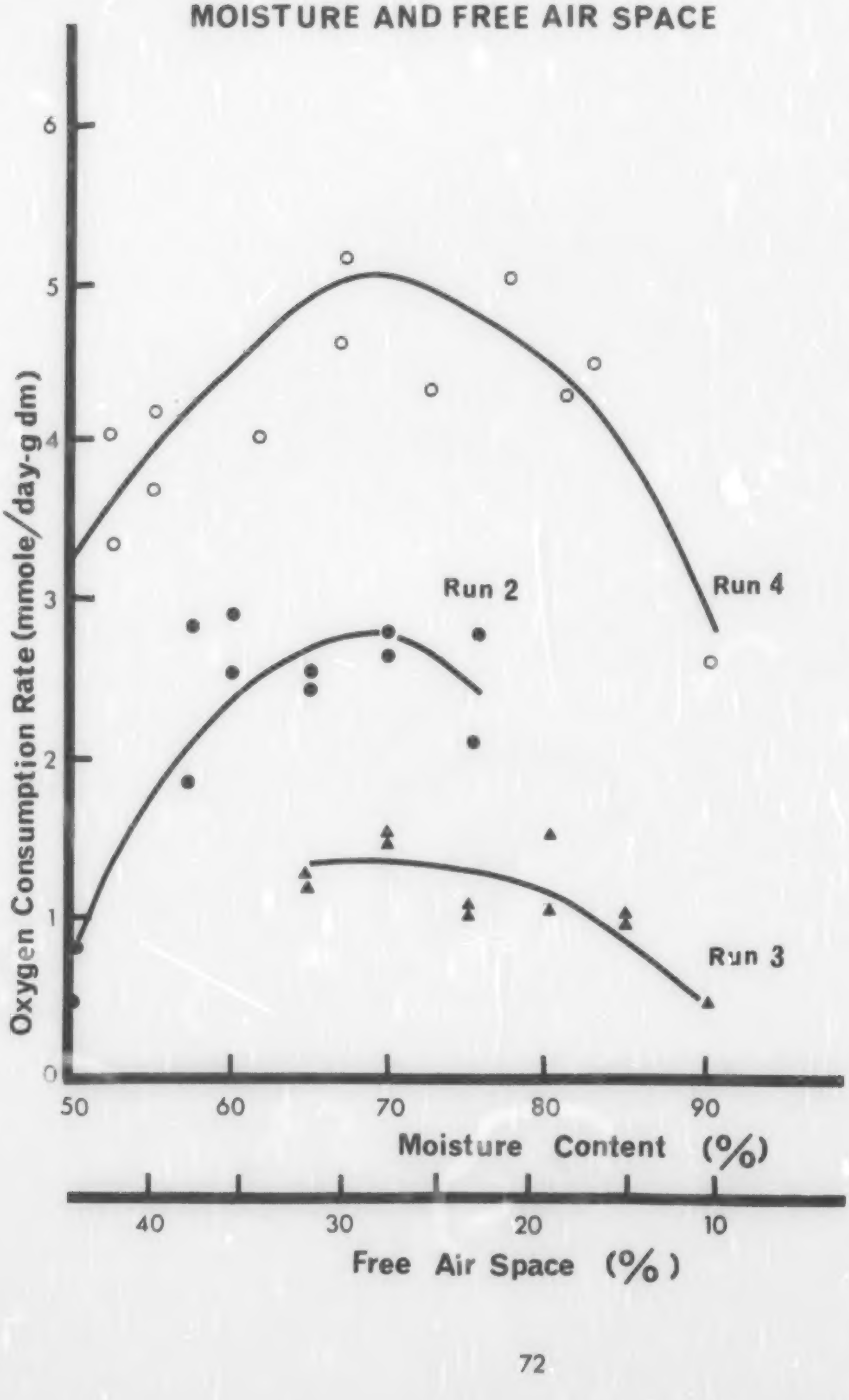
weight basis, equal portions of fresh refuse and seed. The liquid content of each sample was adjusted with tap water to obtain moisture levels from 90 to 50 percent. This corresponds to free air space values of 11 to 44 percent, respectively, for the refuse used. The lower moisture content was set at 50 percent since the rate of stabilization of municipal refuse is significantly reduced below this level (12). The pH of the samples for all runs was approximately 8.

The first run contained samples with free air space values of 23 to 44 percent (75 to 50 percent moisture). The free air space range of 11 to 31 percent (90 to 65 percent moisture) was studied in the second run. The purpose of overlapping the runs from 23 to 31 percent free air space (75 to 65 percent moisture) was to obtain more data in the typical operational range of full-scale composting operations (21,22). The final run consisted of samples with a free air space of 11 to 43 percent (90 to 52 percent moisture).

The oxygen consumption rates for runs 2 and 3 are shown graphically in Figure 19. The oxygen uptake rate increased as the free air space decreased from 44 to 31 percent (moisture increase from 50 to 65 percent). Maximum oxygen consumption rates occurred between 32 and 28 percent free air space (65 to 70 percent moisture). This indicates that additional moisture improves the efficiency of the aerobic stabilization. Free air space greater than 28 percent was sufficient to allow the oxygen requirements of the flora to be met in the refuse used in these studies. As the free air space was decreased from 28 to 11 percent (70 to 90 percent moisture), the air filled voids within the waste decreased in volume, thus restricting reaeration. The maximum oxygen consumption was 2.75 and 1.40 mmole/day gdm, respectively.

The batches of refuse used for runs 2 and 3 were collected 5 and 10 days respectively before these runs. The low stabilization rates obtained for run 3 are believed to be the result of degradation of easily utilized components of the refuse during the storage period.

Figure 19
OXYGEN CONSUMPTION RATE
vs
MOISTURE AND FREE AIR SPACE



The purpose of the third run was to obtain the oxygen consumption rates for the entire range of free air space between 11 and 43 percent (90 to 52 percent moisture). All samples were prepared from a single fresh batch of refuse collected 3 days prior to the run. The results of run 4, included in Figure 19, show that a maximum oxygen consumption rate of 4.95 mmole/day-gdm was obtained when the free air space was approximately 30 percent (67 percent moisture). The oxygen uptake rates obtained with free air space of 11 and 43 percent were less than 80 percent of the maximum rate. Balling occurred in the flasks containing samples with less than 23 percent free air space (75 percent moisture).

In order to determine if the results obtained in each of the three runs were comparable, mathematical expressions for the effect of moisture content on the oxygen consumption rate were determined for the data obtained. An equation was assumed to approximate the form:

$$y = ax^2 + bx + c \qquad (6)$$

Where:

y = oxygen consumption rate (mmole/day-gdm)
x = moisture content (%)
a, b, c = constants

The procedure for the mathematical analysis to evaluate the coefficients has been outlined in Section VI-A Temperature.

The data for each run was represented by the following equations:

Run 2; 24% to 44% FAS (75% to 50% moisture)

$$y = -.0060x^2 + .824x - 25.48 \qquad (13)$$

Run 3; 12% to 32% FAS (90% to 65% moisture)

$$y = -.0035x^2 + .501 - 16.56 \qquad (14)$$

Run 4; 12% to 42% FAS (90% to 52% moisture)

$$y = -.0042x^2 + .590x - 15.70 \qquad (15)$$

The numerical values of the coefficients "a" and "b" are similar for each of the runs. The numerical values of the coefficients "c" are significantly different and indicate the relative magnitude of the oxygen consumption rate obtained for the runs. The major contributing factor for this difference in the value of "c" was the varying length of storage of the refuse.

The optimum moisture content found in each run was determined by differentiating and solving equations (13), (14), and (15). The results summarized in Table 23 indicate approximately 67 percent moisture and 30 percent free air space were optimum. Further, 95 percent of the maximum oxygen consumption rate was obtained when the moisture content was between 63 and 79 percent. The "effective liquid content" (29) was approximately 70 percent.

TABLE 23

OPTIMUM CONDITIONS FOR COMPOSTING MUNICIPAL REFUSE

Run	Oxygen Consumption (mmole/day - gdm)	Free Air Space (%)	Moisture Content(%)	Effective Liquid Content(%)
1	2.75	30.0	67.0	70.1
2	1.40	29.5	67.3	69.3
3	4.95	30.0	67.0	70.5

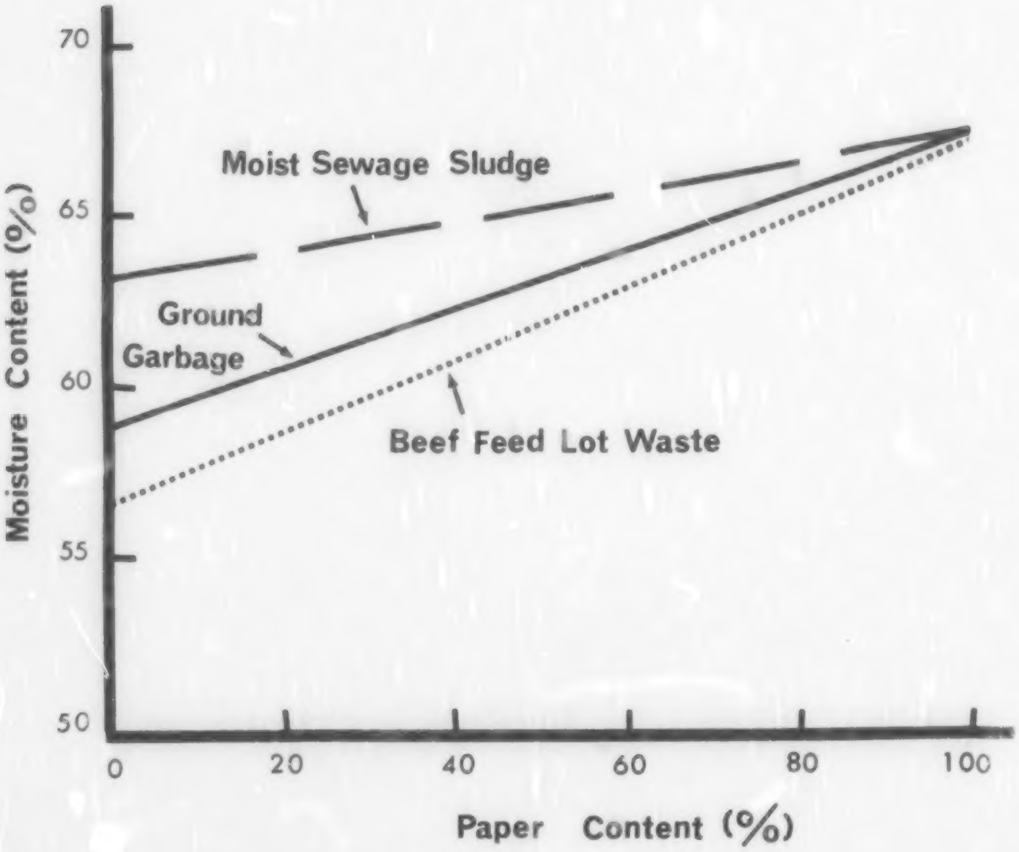
The moisture requirement of 67 percent for stabilization of refuse containing a significant amount of paper found in this investigation is greater than values reported in past studies using mixed refuse. In previous composting research, the typical refuse treated contained only small amounts of paper. However, the most suitable moisture content for stabilizing municipal refuse biologically may depend, to a large extent, on the amount of paper present in the solid waste. To determine the magnitude of the effect, calculations were performed using Equation 12 for mixtures of several solid wastes and paper, maintaining a constant free air space of 32 percent. The results for mixed refuse, sludge and beef lot wastes are presented in Figure 20. The results show that the moisture requirements increase linearly with paper content with constant free air space.

The amount of paper in municipal refuse is not uniform. Waste paper concentration is generally greater in urban areas than that in rural sections of the country. Furthermore, throughout

Figure 20

MOISTURE CONTENT FOR INCREASING PAPER

-Maintain 32 % FAS-



the country the concentration of paper and other cellulolytic materials in municipal refuse is increasing annually. (19).

The free air space concept suggests a more fundamental and universally applicable parameter for optimum composting of not only municipal refuse, but many other types of organic wastes. Information reported in the literature and shown experimentally indicates that 30 to 36 percent free air space is required to obtain optimum composting for a wide variety of materials.

C. Recycle

The need and value for recycling seed material with mixed refuse in composting operations has been open to debate for a considerable length of time (31). Most composting studies have strongly indicated that any type of "starter" material is unnecessary (16). The APWA (8) has indicated that between 1 and 10 percent recycle is beneficial to continuously operated mechanical compost systems. On the other hand, Schulze (11) found that continuous thermophilic composting should be maintained with daily feed rates of 8.4 to 18.3 percent. Thus, for a completely mixed system, these feed rates would correspond to 91.6 and 81.7 percent seed, respectively. The differences in the recycle requirements become obvious when examining the nature of the various composting processes in use.

The primary methods of composting municipal refuse in the United States fall into two general categories; modified windrow composting and continuous mechanical digestion (8). Windrow methods are typically operated as long term batch processes. For batch composting, the environmental conditions and the microbial population are continually changing during the stabilization process. Due to the dynamic nature of the batch process and the large number of microbial species indigenous to mixed refuse,seed material would be useful only if the microorganisms in any emerging environment were unable to multiply at a rate sufficient to take advantage of the conditions at that time. Goleuke et al (31) reported that no significant increase in the stabilization rate of mixed refuse could be attributed to the addition of active composting seed or other inocula in Windrow piles.

Since only a limited degree of mixing occurs during treatment and the amount of recycled seed used has been meager, many mechanical flow through type composting plants may operate biologically as batch systems. Recycling 1 to 10 percent seed therefore might not provide a significant improvement in operation.

True continuously operated composting occurs only when the entire mass of material being treated is well mixed during treatment (22). For this type of system the composting process can be operated close to the optimum environmental conditions. The initial lag in the rate of stabilization associated with batch processes could be eliminated using continuously fed completely mixed systems. Under completely mixed, daily fed operation as reported by Schulze (11), quasi-equilibrium conditions probably were attained, in which a highly specialized flora developed in the composting mass. The use of a large recycle rate enabled the microbial population within the compost to maintain temperatures within the thermophilic range 50 to 70C. These temperatures have been found to be the most efficient range for stabilization of mixed refuse (11), (15).

The purpose of this phase of the research was to investigate the effect of recycle on the rate of composting, as measured by the oxygen consumption rate, in completely mixed composting systems using refuse as feed. Preliminary studies were performed using the Warburg respirometer with mixtures of raw refuse and 0 to 90 percent seed recycle. These results indicated the approximate range of recycle to be used for further experiments in the continuously operated bench scale composters.

Generally, information of this type should be useful to engineers and operaters for determining the relationship of seed recycle and composting rate for mixed refuse. Knowledge of the effect of seed on the oxygen utilization rate will enable an economic balance to be made between the increase of the capital costs associated with the use of recycle and the decrease in operating costs associated with improved waste stabilization rates.

1. Warburg Experiments

Preliminary experiments were performed using the Warburg respirometer to investigate the effect of seed recycle on the composting rate for a typical mixed refuse. Runs 5, 6, 7, and 8 were made with samples of refuse mixed with different amounts of seed acclimated in the bench scale composters operating at the desired temperature conditions to simulate recycle concentrations of 0 to 90 percent. Controls containing seed only were included in all runs. Different refuse batches were used for each run with pH varying between 5.4 and 7.6. The pH level of samples at each recycle concentration increased with seed content as shown in Figure 21. The seed had a pH of 7.9 to 8.4. The free air space was approximately 30 percent in the experiments with a moisture content of 65 to 70 percent. Studies were performed at temperatures of 50.8 and 59.6C.

A lag time in obtaining the maximum rate occurred for the samples with less than 50 percent seed. Oxygen consumption rates typically increased linearly with time at maximum rates for the initial 8 to 10 hours of operation, then gradually decreased after 10 hours. Experimental runs were terminated after 26 to 30 hours.

The effect of seed concentration on the oxygen consumption rate at 50.8C is presented in Figure 22. Similar information obtained at 59.6C for three runs is presented in Figure 23. The results show that at 50.8C, the composting rate was small with no seed and increased to a maximum of 2.9 mmole/day-gVM with 75 percent seed.

In two of the three runs conducted at 59.6C, the effect of seed content on the composting rate was similar to the results obtained at 50.8C. The composting rate was the smallest with zero seed content while the maximum oxygen consumption rate of 3.3 mmole/day-gVM was measured with 75 percent seed.

The results of the final run were unlike those previously obtained as the oxygen consumption rates were 2.6 mmole/day-gVM with zero seed content and increased to 3.4 mmole/day-gVM with 50 percent seed. The significant composting rate in the samples with no seed was believed to be the result of the development of thermophilic microorganisms indigenous to the refuse during storage.

Shredded refuse generally was obtained every other week and stored in a metal container at room temperature. Material

Figure 21

EFFECT OF SEED CONCENTRATION ON THE INITIAL pH

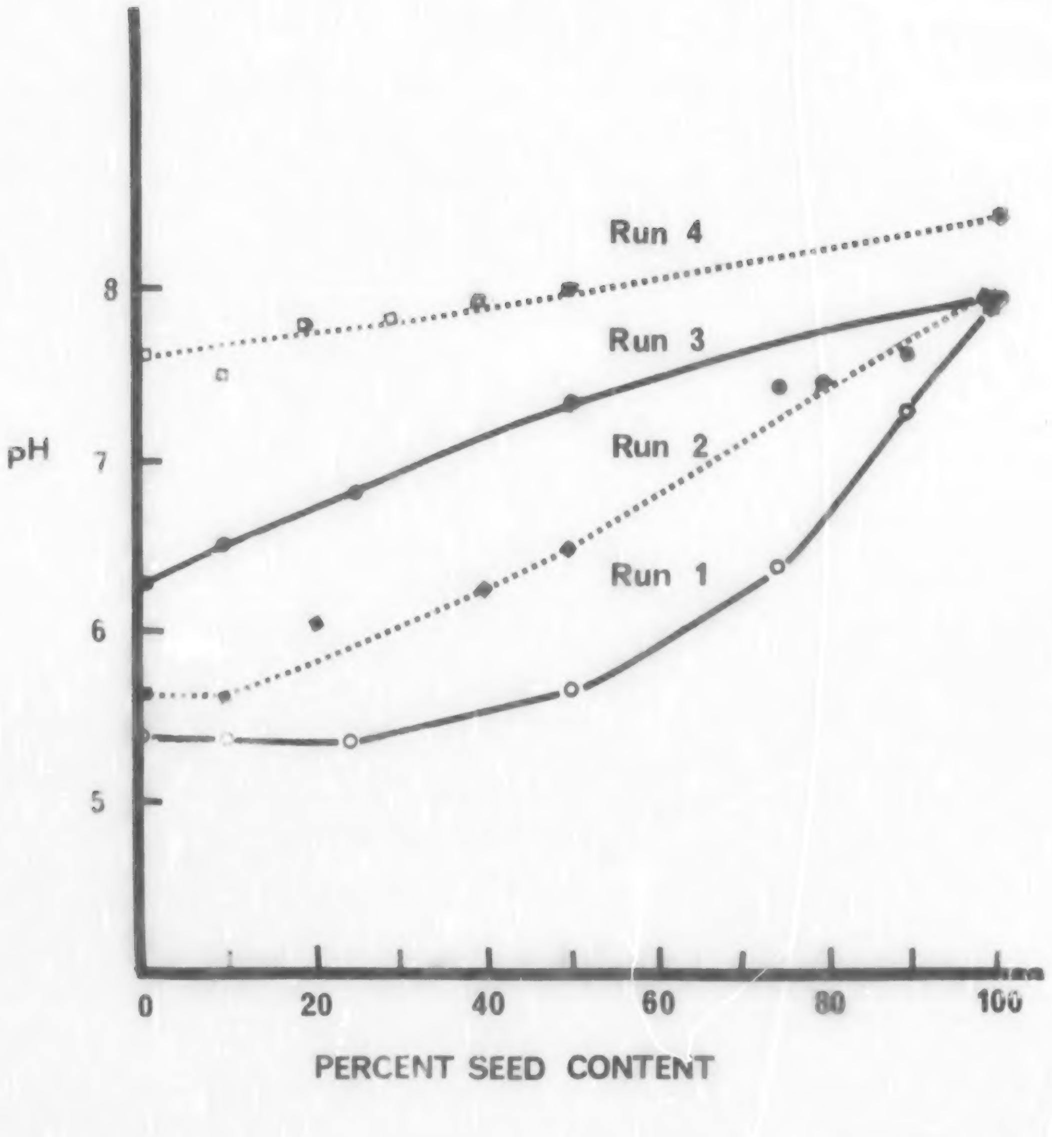


Figure 22

EFFECT OF SEED CONCENTRATION ON THE OXYGEN UPTAKE RATE AT 50.8°C

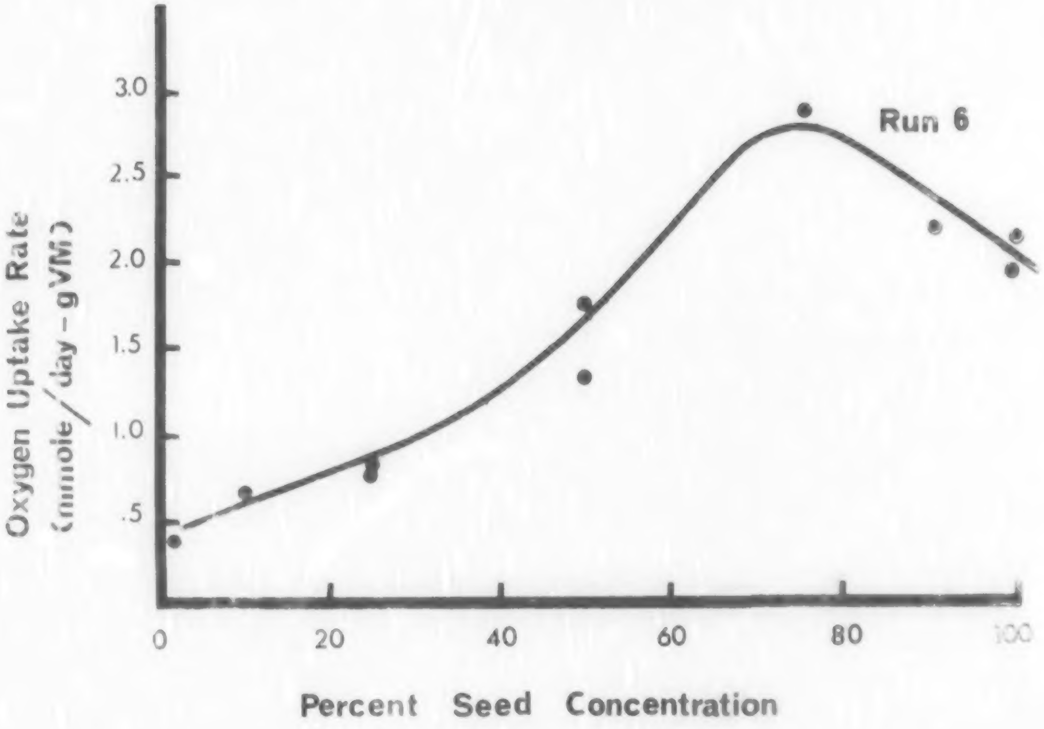
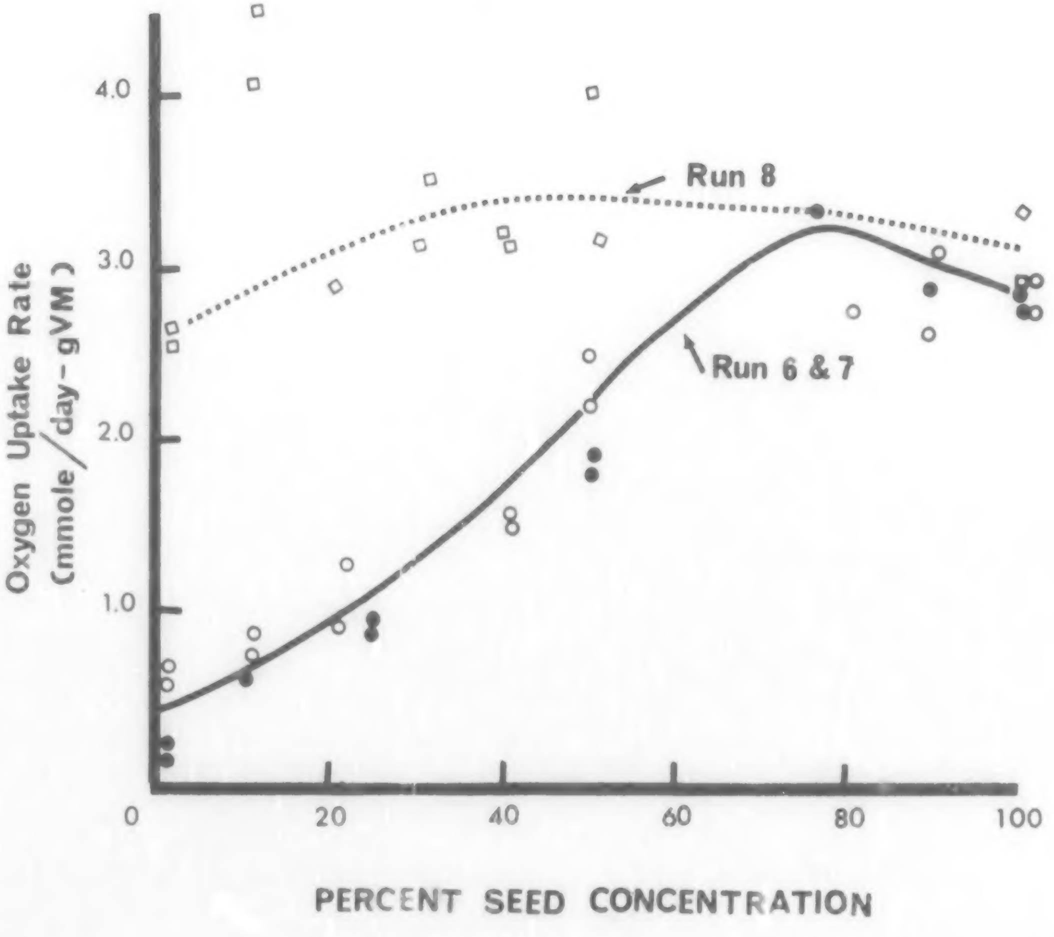


Figure 23

EFFECT OF SEED CONCENTRATION ON THE OXYGEN UPTAKE RATE AT 59.6°C



was removed daily for use as feed for the bench scale composters and other experiments. The temperature of the refuse during storage was normally near that of the ambient air 17 to 22C. Thermophilic microorganisms would not reach a significant level of activity at these temperatures. The particular batch of refuse used for the fourth run had been collected, shredded and stored for two days when used in the Warburg experiments. The temperature of the mass in the metal container at this time was 44C. The pH of the refuse was 7.6 which is unusually high. Normally alkaline pH levels occur when the bench scale composters are operating efficiently. Therefore, microorganisms suitable for composting were probably stimulated by the favorable pH and temperature conditions and were in a highly active state when the refuse was used in the experiments. The storage conditions for the run were not typical since refuse would not normally be stored in a manner to allow for such a significant increase in temperature. The maximum composting rate was generally obtained in Warburg experiments using approximately 75 percent seed, for the conditions studied. The results were affected by the method of storage of the refuse used as feed.

2. Bench Scale Composters

The oxygen consumption rates at seed recycle concentrations of 25 to 75 percent were investigated using the bench scale composters. Five runs numbered 8, 9, 22, 23, and 24 were made.

In the first two runs, batches of an actual mixed refuse were used as the source of feed during the experimental period. The final three studies were made using a mixed refuse prepared in the laboratory. Each of the composters contained between 2,000 and 3,000 g of refuse having a moisture content of 60 to 68 percent. For the mixed refuse used, this moisture content represents from 28 to 36 percent free air space. Values of free air space with this range were previously shown to provide optimum results for composting. The operating pH level was approximately 8.0 for all composters in the five runs. Rotation of the composters, for 2 revolutions each 2 hour cycle, provided mixing of the composting mass. The composters were adjusted to the desired temperatures between 50 and 70C ± 2C. Material was removed from each of the composters every 24 to 72 hours, and replaced with fresh refuse to simulate 25, 50 and 75 percent seed recycle ratios. Recycle concentration refers to the initial percentage of total weight (dry basis) that had been in the composter since the previous feeding and the remaining mass being refuse. On this basis, 100 percent seed recycle could never be obtained. The mass turnover time in the composters for the five runs was 2.5 or 4 days.

Typically the oxygen consumption rates, measured automatically every 4 hours followed a cyclic pattern between feeding intervals. In composters with 50 and 75 percent seed, the rate of oxygen consumed increased to a maximum 5 to 10 hours after feeding and gradually decreased until the next addition of refuse. With 25 percent recycle, the composting rate was more uniform but was less than that of the composters with larger recycles. Representative oxygen consumed data obtained during Run 8, for 50 and 75 percent seed is presented in Figures 24, 25, and 26.

The average composting rates calculated using a planimeter were determined to compare the results for each run. Pertinent results showing the effect of seed on the composting rate recycle are summarized in Table 24, and indicate that composting rates were effected by temperature, seed concentration and time lapsed between feeding intervals. In Runs 8 and 9 using 72 and 75 percent seed and approximately a 4 day mass turnover time, an average oxygen utilization rate of 1.9 mmole/day-gVM was obtained at 50C which increased to 3.7 mmole/day-gVM at 63C. For 50 percent seed recycle the average composting rate was 1.9 mmole/day-gVM at 65C.

The decrease in the composting rates after 10 hours indicates readily degraded components in the refuse were utilized. The feeding interval was reduced from 2 to 1 day to obtain 50

PB-215 801

A Citizen's Guide to Clean Air

Conservation Foundation

prepared for
Environmental Protection Agency

JANUARY 1972

Distributed By:
NTIS
National Technical Information Service
U. S. DEPARTMENT OF COMMERCE

PB 215 801

a citizen's guide to clean air

NATIONAL TECHNICAL
INFORMATION SERVICE
[illegible]

A CITIZEN'S GUIDE TO

clean air

THE CONSERVATION FOUNDATION
1717 Massachusetts Ave., N.W., Washington, D.C. 20036

Prepared by the Conservation Foundation, 1717 Massachusetts Avenue, N.W. Washington, D.C. 20036, under contract with the U.S. Environmental Protection Agency.

Library of Congress Catalog Card Number: 71-187901

January, 1972

Preceding page blank

FOREWORD

In 1970 the Conservation Foundation published *Your Right to Clean Air*, a manual designed to help citizens participate in air quality control processes. It soon became clear that the manual was giving people and organizations concerned with unhealthy air the know-how and the encouragement they needed to exert their interests—collectively the public interest—in clean air programs. Some 49,000 copies were distributed throughout the United States.

In the last days of 1970, government control procedures were changed radically when Congress attached major amendments to the Clean Air Act. The federal revisions make necessary corresponding changes in state and local programs. New time schedules have been set, accelerating the entire control process, and important new avenues have been opened for public participation in decisions affecting every community's air.

These major changes in federal law, accompanied by a thorough restructuring of environmental administration within the federal government, meant that our manual required substantial revision. The Environmental Protection Agency commissioned the Foundation to prepare and publish a revised edition of *Your Right to Clean Air*. As the work evolved, however, it became clear that the new version would bear only slight resemblance to its predecessor. Thus, it was decided to give this pamphlet a new title, *A Citizen's Guide to Clean Air*.

The Conservation Foundation is wholly responsible for interpretations of the control process and for the advice on citizen initiatives given in these pages. Such phrases as "in our opinion" and "in our view" stem from the Foundation, not from EPA. Moreover, since many persons will use this as a reference book, there has been no attempt to banish all repetition from the text. Each chapter is intended to stand more or less on its own. However, a cover-to-cover reading will expand one's appreciation of the complexities of environmental administration and of the many opportunities for citizens to share in it.

Several members of the Foundation staff participated in the writing, editing, and preparation of this manual. Primary credit should go to Miss Mary Ann Massey, who did most of the research and writing.

We hope this work will facilitate the effective involvement of informed citizens in the functions of government.

SYDNEY HOWE, *President*
The Conservation Foundation
January, 1972

CONTENTS

FOREWORD, 5

1. THE CHALLENGE, 11
   - We Can Have Clean Air, 11
   - How Serious Is Air Pollution?, 12
   - (Table: National Emissions of Major Air Pollutants), 14

2. THE CLEAN AIR AMENDMENTS OF 1970, 15
   - What the Act Says, 16
     - Air Quality Control Regions, 16
     - Criteria Documents, 16
     - National Ambient Air Quality Standards, 17
     - Implementation Plans, 17
     - Standards of Performance, 17
     - Hazardous Air Pollutants, 18
     - Auto Emission Controls, 18
     - Monitoring and Public Information Rights, 18
     - Federal Enforcement, 18
     - Citizen Suits, 19

3. THE FIRST STEPS IN THE FEDERAL PROCESS, 20
   - What You Have to Work With, 20
   - What You Have to Know, 21
   - (Table: Environmental Protection Agency), 22
   - How Is the Air Where You Live?, 23

Can It Be Cleaned Up?, 24
Setting National Ambient Standards, 24
(Table: National Ambient Air Quality Standards), 25

4. IMPLEMENTATION PLANS, 27
Regional Classifications, 27
Elements of a Plan, 29
Legal Authority, 29
Control Strategy, 30
Compliance Schedules, 31
Emergency Episode Procedures, 32
Surveillance Systems, 33
Review of New Sources, 34
Resources, 35
Interstate Cooperation, 35
Public Participation, 35
Public Hearings, 36
Public Reporting, 37
Plan Approval, 37
Revisions and Extensions of the Plan, 38
Revisions, 39
Extensions, 39

5. STANDARDS OF PERFORMANCE, 42
National Standards of Performance (New and Modified Sources), 43
State Standards of Performance (Existing Sources), 45
Permit Systems, 46

6. HAZARDOUS AIR POLLUTANT STANDARDS, 47

7. AUTO EMISSION CONTROLS, 50
Individual Contributions to Control, 50
Provisions of the Act, 52
Fuels and Additives, 54
Low-Emission Vehicles, 55
State Responsibilities for Auto Emission Control, 55

8. THE CITIZEN'S LEGAL RIGHTS, 58
Clean Air Amendments, 58
Two Other Federal Acts, 61
National Environmental Policy Act, 61
The Freedom of Information Act, 62
Television, Radio and the "Fairness Doctrine", 62

Legal Resources on the State Level, 63
Assistance from National Legal Organizations, 64

9. ECONOMIC CONSIDERATIONS, 65
Sources of Economic Information, 68
Emission Taxes, 69

10. THE CITIZEN'S ROLE IN POLICY-MAKING, 71
Public Information, 71
Public Hearing Procedures, 72
Funding, 73
Government Structure, 76
A Summing Up, 79

APPENDIX, 80
Glossary, 80
Notes on Some Pollutants, 83
Oxides of Sulfur, 84
Particulate Matter, 84
Carbon Monoxide, 84
Photochemical Oxidants, 85
Hydrocarbons, 86
Oxides of Nitrogen, 87
Asbestos, 88
Beryllium, 89
Mercury, 89
Bibliography, 90
Addresses for Agencies and Organizations, 94

1.

THE CHALLENGE

WE CAN HAVE CLEAN AIR

Restoring quality to the air we breathe ranks among the most challenging environmental tasks of our time. Implicit in the task is a testing of our will, both as individual citizens and as a nation. We know that we can have cleaner air; the question is, "Will we do what we must to achieve it?"

There is little that any of us can do alone to reduce or control air pollution. We can refrain from open burning of trash. We can make sure that our furnaces and automobiles operate efficiently. We can use more public transportation, and we can cut down on our use of electricity and other forms of energy. But even if most of us did these things, there would be little reduction of pollutants in the atmosphere. And besides, increases in population, urbanization, mobility, and consumption would offset such small abatements.

But there is much more that we can do to help achieve cleaner air. We believe that a great deal can be accomplished by groups of citizens working together at the local level. This manual is designed to further such cooperative endeavors by introducing interested citizens to some of the elements of effective air pollution control programs. It is designed to provide basic information about air pollution itself, along with suggestions about citizen participation and the opportunities open to those who want to influence clean-up efforts in their own communities.

Preceding page blank

HOW SERIOUS IS AIR POLLUTION?

Just as we all are responsible for air pollution to some degree, so are we all the victims of its harmful consequences. These vary with time and place and person, but few of us escape the ill effects of dirty air.

Air pollution can kill. In London, New York, and Donora, Pennsylvania, polluted air—sustained and heavy for several days—has caused serious illness and death, especially among infants, the elderly, and people with weakened hearts or lungs.

Air pollution can impair health. Dirty air makes eyes water and smart; it stings the throat and upsets breathing. People with chronic lung or heart disease are particularly vulnerable to air pollution. We are just beginning to measure the adverse health effects that can result from continuous exposure to relatively low concentrations of pollutants. Epidemiological studies indicate that direct relationships exist between prolonged exposure to polluted air and the incidence of emphysema, bronchitis, asthma, and lung cancer.

. . . people who died were those afflicted with lung disease, heart disease, the aged, and children under one year. . . . studies done in New York and . . . being conducted in Chicago now suggest that on high pollution days there are more deaths related to heart and lung disease than there are on low pollution days. Our studies are very preliminary but the implications are there.

Bertram W. Carnow, M.D., University of Illinois School of Medicine, address to the Southeastern Wisconsin Air Quality Workshop, November 18, 1969.

Equally alarming are the strong indications that the urban poor are more susceptible to acute respiratory illness—probably as a result of their living conditions and the high levels of pollution to which they are exposed.

More obviously, of course, air pollution reduces visibility. It can spoil scenic vistas. It can ground planes and make driving hazardous. Its corrosive qualities cause vast economic losses and contribute to the deterioration of cities. It rots and soils clothes, discolors house paints, and rusts metals. By eating away stone and metal, it mars monuments and public buildings and increases housekeeping chores and costs for cities, families, and businesses. The Library of Congress says its books and manuscripts deteriorate more rapidly because of air pollution. The National Gallery of Art suspects that air pollution is damaging masterpieces.

The Environmental Protection Agency estimates the dollar costs of air pollution—in terms of damage to vegetation, materials, property, and health—at $16 billion per year, or about $80 for each person in the U.S. Of this total, the costs of human illness and death are estimated in the neighborhood of $6 billion.

Damage from air pollution is not just an urban phenomenon. It affects rural areas, too, by injuring vegetation, stunting the growth of shrubs and flowers, severely damaging crops and trees, and causing illness among livestock. To many farmers, these costs are apparent and direct. But to most of us, they come indirectly—in the form of higher food bills and, from time to time, contaminated foods.

One classic illustration of the devastation wrought by air pollutants is in the Copper Basin area of Tennessee, where about 7,000 acres of once rich deciduous forest were completely denuded and another 17,000 acres replaced with grassland species following the destruction of the native forest species. Gully erosion stripped away the soil, and even the climate was altered. . . .

Michael Treshaw, *Phytopathology*, August, 1968.

Air pollution needlessly wastes essential natural resources. Nearly 17 million tons of sulfur were emitted into the atmosphere in 1969, and the amount had been increasing every year. Yet sulfur is a valuable natural resource. And there is growing evidence that air pollution may be having adverse effects on the growth and reproduction of some of our forests. Those on the southern edge of Glacier National Park are believed to have been seriously damaged by fluorides emitted from a nearby aluminum plant; trees in the San Bernardino Mountains are dying from smog produced in Los Angeles, 30 miles away.

Air pollution threatens the delicate, complex natural systems on which all life depends. Undesirable ecological changes may well be its most dangerous long-range result. Signs of climatic alterations are already appearing, at least on a small scale, and some scientists are concerned about the ultimate global effects of increasing concentrations of carbon dioxide (CO_2) in the atmosphere. In 1969, we poured 281 million tons of pollutants into the air in the U.S. alone, ignoring the danger that we might be degrading our environment beyond repair and that we might become a nation of respiratory cripples.

Environmental pollution . . . now affects the whole earth. Smog produced in urban and industrial areas is hovering over the countryside and beginning to spread over the oceans . . . cities will not benefit much longer from the cleansing effects of the winds for the simple reason that the wind itself is contaminated.

Dr. René Dubos, The Rockefeller University, *The New York Times*, January 6, 1969.

NATIONAL EMISSIONS OF MAJOR AIR POLLUTANTS: 1969

(latest year for which figures are available)

(millions of tons per year)

Source	*Sulfur Oxides*	*Particulate Matter*	*Carbon Monoxide*	*Hydrocarbons*	*Nitrogen Oxides*	*TOTAL*
Transportation	1.1	0.8	111.5	19.8	11.2	144.4
Fuel Combustion in stationary sources	24.4	7.2	1.8	0.9	10.0	44.3
Industrial processes	7.5	14.4	12.0	5.5	0.2	39.6
Solid waste disposal	0.2	1.4	7.9	2.0	0.4	11.9
Miscellaneous	0.2	11.4	18.2	9.2	2.0	41.0
TOTAL	33.4	35.2	151.4	37.4	23.8	281.2

NOTE: Sulfur oxides are expressed as sulfur dioxide and nitrogen oxides as nitrogen dioxide in this table.

SOURCE: Environmental Protection Agency.

2.

THE CLEAN AIR AMENDMENTS OF 1970

What is being done about air pollution control? Obviously not enough. We have been slow to recognize the extent of air pollution and the seriousness of the threat it constitutes to our health and well-being.

The first federal control act, passed in 1955, was pretty much restricted to research into the nature and extent of the nation's air pollution problem. The 1963 Clean Air Act authorized grants to state and local agencies to assist them in their own control programs. It also gave some limited authority to the federal government to take action to abate interstate pollution problems. This basic federal control authority was expanded and strengthened by the 1967 Air Quality Act. One of its more significant measures gave citizens a statutory right to participate actively in the control process through public hearings. In many communities all over the country, citizens seized this opportunity to become forceful and effective advocates for clean air.

Now, with the passage of the Clean Air Amendments of 1970,* there are far stronger legal tools for air pollution control and an even larger mandate for citizen participation.

Basically, the theory of the federal air pollution control program has been changed only slightly from the statement in the original law of 1955, which said: "The Congress finds . . . that the prevention and control of air pollution at its source is the primary responsibility of states and local governments." This is still the case. But now, if the states fail to meet their control responsibilities, the federal government, acting through the newly established Environmental Protection Agency (EPA), has an increased responsibility and authority to enforce pollution controls.

---

* Hereafter referred to as "the Act."

WHAT THE ACT SAYS

Here is a digest of the major provisions of the amended Act (Public Law 91-604). Some of these will be discussed in more detail in later chapters. The numbers in parentheses which accompany each heading refer to the corresponding sections of the Act.

Air Quality Control Regions (Sec. 107)

See Chapter 4

EPA, assisted by the states, is to designate air quality control regions. These are the basic geographic units in which the control process takes place. Regional boundaries are based on considerations of climate, meteorology, topography, urbanization, and other factors affecting air quality conditions in each area. A region can cover only part of one state or it can include portions of several states which share a common air pollution problem. The country has been divided into about 250 regions. As pollution patterns change or as more information about problems is gathered, the boundaries of some of the regions may change. (Ask your regional EPA public affairs officer or your state air pollution control agency for a description of the control region in which you live. See page 94 for addresses of EPA's regional offices.)

Criteria Documents (Sec. 108)

See Chapter 4

EPA is required by law to develop air quality criteria for the major pollutants: particulate matter, sulfur oxides, hydrocarbons, carbon monoxide, and so on. These criteria, which are issued in "criteria documents," give the levels at which these pollutants—by themselves and in combination with other pollutants—are known to have adverse effects on public health or welfare. (See page 83 for a list of pollutants.)

Simultaneously, EPA provides information on control techniques for each of these pollutants, describing the methods available to reduce emissions. Such information must include the latest technology, the costs of emission control, and the economic feasibility of alternative control methods. EPA is required to review both criteria documents and control-technology documents from time to time and to revise them as new knowledge becomes available.

National Ambient Air Quality Standards* (Sec. 109)

See Chapter 4

A national ambient air quality standard is the maximum level which will be permitted for a given pollutant. But there are two kinds of such standards: primary and secondary. Primary standards are to be sufficiently stringent to protect the public health; secondary standards must protect the public welfare.

EPA sets these standards after it issues a criteria document and a control-technology document on the pollutant in question.

Both the primary and secondary standards apply to all control regions.

Implementation Plans (Sec. 110)

See Chapter 4

Within nine months after EPA issues primary and secondary national ambient air quality standards for a pollutant, each state must formulate an "implementation plan" to meet, maintain, and enforce those standards in each air quality control region within its jurisdiction. The states must hold public hearings on these plans, adopt them, and submit them to EPA for approval. Each state plan must provide for the attainment of primary standards within three years of EPA's approval of the state's plan; secondary standards must be attained within a "reasonable time." If a state fails to submit a satisfactory plan, EPA has the authority to write its own plan for the state, which the state must then carry out.

Standards of Performance (Sec. 111)

See Chapter 5

The Act requires EPA to set "standards of performance" for new and "modified" stationary sources of pollution. These standards are distinct from the ambient air quality standards described above. They constitute direct emission limitations for all major pollutants from specified *types* of sources, such as portland cement plants and municipal incinerators.

All standards of performance are applicable nationally, but only to sources in a category specified by EPA. They apply principally to new pollution sources. But they also apply to existing sources whenever "modification" (physical change or change in the method of operation) results in increased emissions of old pollutants or in new emissions of new pollutants.

For all existing *un*modified sources in the specified categories, the states are required to set state performance standards, under procedures to be established by EPA. EPA will also prescribe procedures under which the states may choose to enforce the federal standards for new and modified sources.

---

* "Ambient" as used in the term "ambient standard" refers to the outdoor air (atmosphere). Thus, ambient standards are limits on the total amount of a pollutant permitted in a region's air.

Hazardous Air Pollutants (Sec. 112)

See Chapter 6

Some pollutants are more toxic than others. For those which are not covered by an ambient standard and which EPA believes "may cause, or contribute to, an increase in mortality or . . . in serious irreversible, or incapacitating reversible, illness," EPA must set emission standards that incorporate "an ample margin of safety to protect the public health." Such pollutants include, for example, asbestos, beryllium, and mercury.

Auto Emission Controls (Sec. 202)

See Chapter 7

The Act itself has set deadlines for controlling major emissions from motor vehicles. Beginning with the model year 1975, emissions of carbon monoxide and hydrocarbons from automobiles and light trucks must be reduced by at least 90 percent from 1970's partially controlled levels. Nitrogen-oxide emissions from model year 1976 autos must be reduced at least 90 percent from the uncontrolled 1971 levels. If automobile manufacturers contend that it is impossible to meet the reduction levels for carbon monoxide and hydrocarbons in time, they may apply to EPA in January, 1972, for a one-year extension of the deadline. If they wish to make the same argument in the case of nitrogen oxides, they may apply to EPA for a one-year extension in January, 1973. EPA is empowered to grant or reject such requests for postponement under certain circumstances. But any extension beyond one year would require authorization from Congress.

Monitoring and Public Information Rights (Sec. 114)

See Chapters 4 & 8

EPA may require states and individual sources to monitor pollutant emissions, to keep records, and to submit periodic reports. All such records and reports are to be considered public information, with one exception: EPA may keep confidential any trade secrets or other information whose public availability the manufacturer has shown to be of potential harm to his business. However, emission data are specifically exempted from such protection.

Federal Enforcement (Sec. 110, 113, 303)

See Chapters 4 & 8

Once standards and implementation plans are in effect, EPA is required to oversee state enforcement. Where widespread violations indicate that the state is failing to enforce a plan, EPA may step in and enforce it. Or EPA may enforce portions of a plan by issuing orders of compliance or bringing civil actions in federal courts for violations. EPA is also empowered to sue for immediate restraint of any pollutant source which is imminently endangering the health of persons—if state or local authorities have failed to abate such pollution under their own regulations.

Citizen Suits (Sec. 304)

See Chapter 8

Any citizen may bring suit against any person or corporation alleged to be violating an emission standard or other limitation applicable under the Act. Citizens may also sue the Administrator of EPA for failure to perform an action required of him by the Act. In cases brought by citizen plaintiffs, the courts are empowered to award the costs of litigation to such plaintiffs whenever the court determines such an award is appropriate.

> *EPA is a new departure, a fresh start, to restore the delicate balance which supports life on this planet. It is a new, integrated approach to the environmental crisis. . . . We are going to insist, with the authority that Congress has provided, and with all the powers of persuasion at our command, that all existing means for controlling pollution be applied, across the board, in every city and town and to every industry in this country. We intend to pursue a vigorous enforcement program as the foundation of our whole effort in pollution control.*
>
> William D. Ruckelshaus, EPA Administrator, March 6, 1971, Portland, Oregon.

3.

THE FIRST STEPS IN THE FEDERAL PROCESS

WHAT YOU HAVE TO WORK WITH

With the establishment of the Environmental Protection Agency in 1970, federal responsibility for combatting environmental pollution was consolidated into one agency. EPA assumed direction of most federal programs for the control of air pollution, water pollution, and noise pollution; for the management of solid waste; and for the regulation of pesticides and radioactive materials. These programs had previously been spread among various Departments, including Agriculture, Interior, and Health, Education and Welfare.

The creation of EPA should enable the government to approach pollution control in a more coherent and more assertive way. It should also facilitate citizen participation in the control process by providing one contact agency in the federal structure.

It is already clear, however, that EPA's performance will depend largely upon the effectiveness with which citizens organize for action and press for pollution control. Interested and informed citizens will have to be involved on a continuing basis if EPA is to do the clean-up job assigned to it by Congress. But the agency will need more than just the watchful eyes of citizens; it will also need their support.

In many cases, sources of pollution will actively advocate the slowing down, weakening, and outright avoidance of the prescribed control process. One agency alone, no matter how strong its legislative mandate, cannot withstand such pressures unless it has a strong base of public support to rely on. This is where you can help. As EPA Administrator William D. Ruckelshaus said in 1971:

"The most important factor to ensure a clean environment is the arousal and involvement of the public. The role of citizen involvement and pressure cannot be overestimated. It makes it much easier for the dedicated administrator and legislator to do right and a whole lot harder for the lax administrator or legislator to do wrong."

EPA, like many other federal agencies, has regional offices with substantial responsibility for implementing the national air quality program. An organization chart of EPA, which includes the location of its ten regional offices, appears on the following page. Write your regional office for the names of the regional administrator, the public affairs officer, and the person in charge of air quality matters. Ask the office to send you announcements of any EPA actions regarding air quality.

EPA has developed programs to encourage citizen participation in federal and state efforts to control pollution. Using the state implementation-plan hearings as a rallying point, the citizen support program is designed to promote the formation of citizen coalitions in different areas of the country. Some funding and professional assistance may be provided to organized citizen groups to encourage their active and continuing involvement in the control process. These community support programs are administered by regional public affairs officers and by the Division of Public Services within EPA's Office of Public Affairs in Washington.

WHAT YOU HAVE TO KNOW

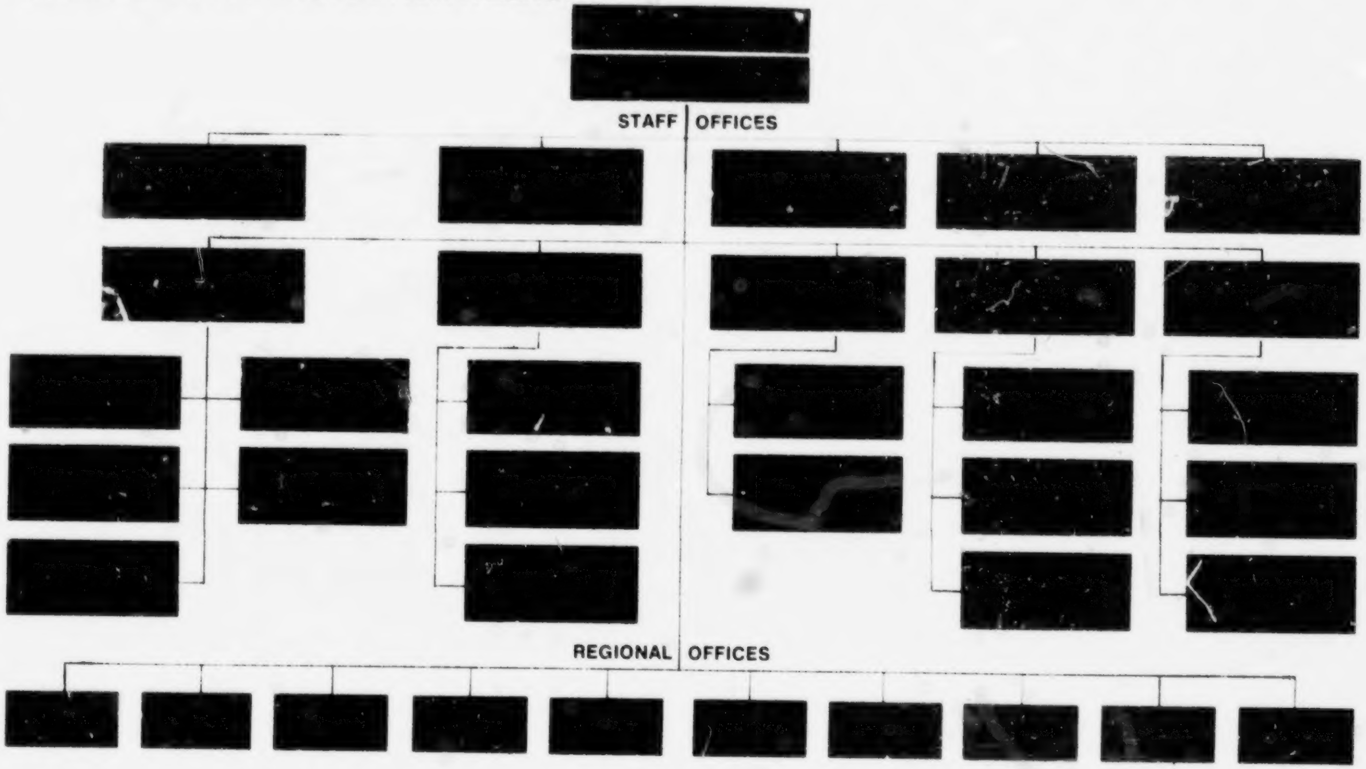
If you are going to help control pollution in your area, you will need to learn a good deal about the existing air quality situation.

First, you will need some basic facts—facts that apply virtually anywhere—about the different pollutants and the levels of concentration at which they are known to be harmful. On page 84 in the Appendix, you will find brief descriptions of the six major pollutants now covered by national standards. These descriptions are drawn from the federal criteria documents, which describe the levels at which harm from given pollutants has been detected.[*]

---

[*] One caution should be sounded here: The criteria describe *currently known* levels at which harm is detectable. If past trends continue, increasing scientific knowledge could confirm the existence of ill effects at even lower levels. For instance, 12 years ago, the industrial health standard for carbon monoxide was 100 parts per million, eight-hour average. In 1967, as a

ENVIRONMENTAL PROTECTION AGENCY



The documents effectively refute arguments that no studies have linked common levels of air pollution with impairment of human health and welfare. They are fairly exhaustive collections of most of the known data on the properties and effects of individual pollutants, by themselves and in combination with other pollutants. They give the effects of different levels and combinations of pollutants on health, visibility, vegetation, and on inert materials such as metal and paint. They also treat known economic losses and other relevant factors which help the citizen judge what limits on particular pollutants make sense.

The criteria documents themselves are voluminous and technical. The current ones cover six pollutants: particulate matter, sulfur oxides, carbon monoxide, photochemical oxidants, hydrocarbons, and nitrogen oxides. Far more useful to the layman is the series of "summary and conclusions" booklets published by EPA on each pollutant. Free copies are available from EPA. (See page 90 for a bibliography of air pollution control information.)

HOW IS THE AIR WHERE YOU LIVE?

After you have studied the criteria summaries, find out how dirty the air is in your community. By comparing air pollution levels in your area with the criteria levels, you can judge the severity of your problem. Your local or state agency should be able to provide information on local pollution levels. These agencies have a responsibility to keep the public informed of air quality conditions and should be issuing regular (and comprehensible) reports. To avoid receiving highly technical or obscure information, make your inquiry as specific as possible. For example, you might seek some or all of the following:

- Results of latest samplings of specific pollutants in your control region, including annual means,* maximum and minimum levels, means in cleanest communities versus means in more polluted communities, number and location of sampling sites, number of samples taken and methods used. (Consider whether these are individual averages from individual sampling sites or averages that combine the figures from several sampling sites throughout the community. If readings from low-pollution sites are averaged with those from one high-pollution site, the resulting figure will be deceptively low.)

---

result of further studies, this standard was changed to 50 parts per million. The recent criteria document for carbon monoxide suggests that even more stringent control levels are necessary. Common sense dictates that standards not be set at levels where harm is known to occur, but at even lower levels, to allow a margin of safety.

* A "mean" is a type of average. See the glossary on page 80 for an explanation of the different kinds of means used.

- Results of emission inventories (including amounts of specified pollutants from all major sources).
- Trends in levels of pollutants based on sampling records.
- Results of any local economic or health effects studies or surveys.
- Descriptions of pertinent meteorological and topographical conditions which influence air quality.
- Copies of existing air pollution control laws (city, county, state and regional) and explanations of the composition and functions of local and state control agencies (e.g., flow charts of enforcement processes), budget totals and allocations.

Compare the levels for each pollutant with the standards on page 25 and with the criteria levels described on pages 84 to 87 to determine the severity of pollution problems in your area.

You may also want to find out which local citizen organizations are already involved in clean-air issues. The local chapter of the Tuberculosis and Respiratory Disease Association, the League of Women Voters, or a university ecological group may have active air quality programs. A local citizens' coalition for clean air may have been formed. Active groups will have information on air pollution problems and on the technical and procedural aspects of the control process.

CAN IT BE CLEANED UP?

Having obtained general information on pollutants and a description of air pollution in your own community, you may want to find out what can be done. The federal control-technology documents, published by EPA simultaneously with the criteria documents for each pollutant, provide this information. These compilations describe the availability and applicability of techniques, their costs and effectiveness, and the feasibility of alternative methods.

SETTING NATIONAL AMBIENT STANDARDS

Now that you know the extent of your community's problems, you can focus on the abatement process outlined in the federal law. But keep in mind an important premise of this law: prevention and control of air pollution are primarily the responsibility of state and local governments.

Even so, the federal role is hardly minor. It is up to EPA to set the guidelines for enforcement, to assist in the establishment of workable programs in the individual states, and to move in as the direct enforcer if and when a state fails to do its own enforcing.

As of this writing, EPA has set the national ambient air quality standards for six major classes of pollutants, as listed in the table below:

NATIONAL AMBIENT AIR QUALITY STANDARDS

Pollutant	*Primary*	*Secondary*
Particulate Matter		
Annual geometric mean	75	60
Maximum 24-hour concentration*	260	150
Sulfur Oxides		
Annual arithmetic mean	80 (.03 ppm)	60 (.02 ppm)
Maximum 24-hour concentration*	365 (.14 ppm)	260 (.1 ppm)
Maximum 3-hour concentration*		1,300 (.5 ppm)
Carbon Monoxide		
Maximum 8-hour concentration*	10 (9 ppm)	
Maximum 1-hour concentration*	40 (35 ppm)	same as primary
Photochemical Oxidants		
Maximum 1-hour concentration*	160 (.08 ppm)	same as primary
Hydrocarbons		
Maximum 3-hour (6-9 am) concentration*	160 (.24 ppm)	same as primary
Nitrogen Oxides		
Annual arithmetic mean	100 (.05 ppm)	same as primary

(All measurements are expressed in micrograms per cubic meter ($\mu g/m^3$) except for those for carbon monoxide, which are expressed in milligrams per cubic meter (mg/m^3). Equivalent measurements in parts per million (ppm) are given for the gaseous pollutants.)

* Not to be exceeded more than once a year

Standards for such other pollutants as fluorides, polycyclic organic matter, and odorous substances may be proposed in the future.

In setting standards for individual pollutants, EPA follows a procedure that all interested citizens should know about. When EPA publishes criteria documents and control-technology documents for any pollutant, it must simultaneously propose national primary and secondary ambient air quality standards for that particular pollutant. These proposed standards are published in the *Federal Register*, a daily compilation of official federal actions. (Many libraries and state agencies subscribe to the *Register*. EPA also maintains a mailing list of persons interested in receiving notice of the Agency's actions; ask your regional EPA public information officer about this.) Within 90 days after publication of proposed standards, EPA must evaluate all comments submitted by interested persons and promulgate its final version in the *Register*. This process was completed on April 30, 1971, for the six major pollutants listed in the table above.

When standards for the other pollutants are proposed, citizens may want to submit their comments to EPA, following the instructions published with the proposals. Generally, you will have between 30 and 45 days to get your statement in. This means that you have to work quickly to obtain the proposals, analyze them, and prepare and mail your comments. Organizations such as the Natural Resources Defense Council and others listed on page 95 may be able to assist you in obtaining and analyzing information.

Major industries have lobbyists working full-time in Washington to represent their interests with federal agencies. Citizens who lack similar resources must rely heavily on the submission of written comments. The potential effectiveness of such action should not be dismissed. When many citizens comment on a proposed action, an agency is put on notice that the public is scrutinizing its role. Such comments to EPA need not be lengthy or technical. You may simply compare EPA's proposed standards with the levels cited as harmful in the criteria documents and give your opinion as to whether adequate margins of safety have been built in. Of course, if you can get lawyers, doctors, engineers, and other "experts" to help you prepare your statement, or even co-sign it, it will strengthen your case. And don't hesitate to seek the support of your Senators and Representatives.

In control regions where the air quality is comparatively good (i.e., where pollutant levels are below those allowed by the national standards), citizens may want to urge state officials to adopt standards for that region that are more stringent than the national ones. (See page 29.)

In doing this, you will probably advance your cause by getting in touch with as many people and organizations as possible and urging them to join you in pressing for more stringent standards. A voice in the wilderness does not impress public decision-makers nearly as much as a number of insistent voters who represent a cross-section of community interests. Since there is an increasing number of "how-to" books which advise you about organizing people for such an effort, this manual omits generalized organizing suggestions.

4.

IMPLEMENTATION PLANS

The national ambient air quality standards represent goals that must be achieved and maintained: they do not, in themselves, clean up the air. The mechanism for achieving the standards is the state implementation plan. Section 110 of the Act requires that, within nine months of the establishment of any national ambient air quality standard, the states submit for EPA's approval a plan which provides for the "implementation, maintenance and enforcement" of that standard. These implementation plans (to be referred to in this chapter simply as "plans") must provide for the attainment of each primary standard within three years and for the attainment of each secondary standard within a "reasonable time."

On August 14, 1971, EPA published a set of regulations entitled "Requirements for Preparation, Adoption, and Submittal of Implementation Plans." These regulations spell out the required basic components of a plan. This chapter describes the major points of the Act and of the EPA regulations.

REGIONAL CLASSIFICATIONS

The units for which the standards are designed are called air quality control regions. The country is now divided into about 250 such control regions. Thus, large states often contain several regions, among which are widely varying pollution levels and problems. One state (Hawaii) itself comprises a single control region. And the boundaries of some control regions encompass parts of two or more states. Obviously, different control measures will be needed from region to region, depending on their location, the nature of the pollution, and the degree of urbanization.

To accommodate these differences in the implementation process, EPA has devised a classification system. Its purpose is, in EPA's words, to ensure that "the time and resources to be expended in developing the plan for that region, as well as the substantive content of the plan, will be commensurate with the complexity of the air pollution problem."

The classification system works like this. Each control region is graded by EPA as Priority I, Priority II, or Priority III, on the basis of the known or estimated levels of the six pollutants presently covered by national standards. Hence, the most heavily polluted regions are Priority I; regions with less pollution are Priority II; and those with pollution levels below or just above standard levels are Priority III.

Moreover, a given control region may have different classifications for different pollutants. It could be classified as Priority I for sulfur oxides and Priority III for carbon monoxide. And some regions, where precise air quality data are lacking, may be classified according to population—for example, any region with an urban concentration exceeding 200,000 people will generally be classified as Priority I. If several regions within one state share the same classification for a given pollutant, the state may develop one plan for that pollutant with provisions applicable to all of those control regions.

Citizens in Priority III regions should be alert to the possibility that their state plan may permit some deterioration of the air quality in their control regions. This would be true when a state plan does not protect the air quality from being polluted up to the standard level. Such deterioration in air quality is a matter of choice among the citizens of the control region and the state. But the Senate Public Works Committee had this to say in its report on the 1970 Amendments:

> . . . Once . . . national goals are established, deterioration of air quality should not be permitted except under circumstances where there is no available alternative. Given the various alternative means of preventing and controlling air pollution—including the use of the best available control technology, industrial processes, and operating practices—and care in the selection of sites for new sources, land use planning and traffic controls—deterioration need not occur.[*]

Later, EPA, in issuing the first six national ambient standards on April 30, 1971, stated that:

> The promulgation of national primary and secondary ambient air quality standards shall not be considered in any manner to allow sig-

---

[*] U.S. Senate Public Works Committee Report No. 91-1196, page 11.

nificant deterioration of existing air quality in any portion of any State.**

Further, the Act allows states to adopt standards for individual control regions that are more stringent than the national ones. Citizens in unpolluted regions should take a hard look at this. They may want to urge their state agency officials, their governor, and their state legislators to protect the quality of the air in their region against deterioration by setting such stricter standards. Ideally, the best way to do this is by having the state agency hold a separate hearing to consider such standards—prior to hearings on an implementation plan. But since lack of time may foreclose this opportunity, an alternative would be to testify in favor of such standards at hearings on the implementation plan itself.

ELEMENTS OF A PLAN

In order to meet EPA requirements, an implementation plan must include provisions for the following major components:

1. Legal authority
2. Control strategy
3. Compliance schedules
4. Emergency episodes
5. Surveillance systems
6. Review of new sources
7. Resources
8. Interstate cooperation.

Each of these is discussed in order on the following pages.

Legal Authority

First, the federal government must be satisfied that the state has the necessary authority to produce and execute an implementation plan. Each plan must contain evidence of that authority. Basically, there must be legal authority to:

1. Adopt emission standards and any other measures necessary to attain and maintain national standards;

2. Enforce all applicable laws and regulations and, when necessary, seek injunctive relief (i.e., a court order to a polluter to cease violating an applicable law or regulation);

3. Take emergency action to abate pollution which substantially endangers human health;

4. Prevent the construction, modification, or operation of any stationary source at any location where its emissions will prevent the attainment or maintenance of a national standard;

5. Obtain any information needed to determine whether sources

---

** Section 410.2(c) Code of Federal Regulations, *Federal Register*, April 30, 1971.

are in compliance with applicable laws. This includes authority to inspect sources, to conduct tests, and to require sources to keep emission records or any other specified records; and

6. Require stationary sources to install, maintain, and use emission monitoring devices and to periodically report on the nature and amounts of such emissions. Such monitoring data and reports must be correlated with applicable emission limitations. (The state must make the emission data and the correlations available to the public.)

Most states do have the authority to set and enforce control standards. Many, however, do not have the requisite authority specified in Nos. 5 and 6 above. Consequently, EPA has ruled that the similar federal powers (under Section 114 of the Act) may be delegated to the states so that they will be able to satisfy these requirements.

There is one other exception. If an implementation plan calls for state regulation of motor-vehicle emissions or for land-use controls, the state does not have to show that it already has the power to carry out such programs through existing laws. But it must include a timetable for acquiring such power (if it does not yet have it).

Control Strategy

Each plan must contain a control strategy—defined by EPA as "a combination of measures designed to achieve the aggregate reduction of emissions necessary for attainment and maintenance of a national standard." It is this "strategy" which tells, in effect, what steps the state intends to take.

EPA's regulations contain the following list of acceptable control-strategy measures:

1. Emission limitations;

2. Federal or state emission charges, or taxes, or other economic incentives;

3. Closing or relocation of residential, commercial, or industrial facilities;

4. Changes in schedules or methods of operating commercial or industrial facilities or transportation systems;

5. Periodic inspection and testing of motor vehicle emission control systems;

6. Emission control measures applicable to in-use motor vehicles, including mandatory maintenance, installation of emission control devices, and fuel conversion to gaseous fuels;

7. Measures to reduce motor vehicle traffic, including commuter taxes, gasoline rationing, parking restrictions, or staggered working hours;

8. Expansion or promotion of mass transportation facilities by increasing the frequency, convenience, and passenger-carrying ca-

pacity of mass transportation systems, or by providing for special bus lanes on major streets and highways;

9. Any other land-use or transportation control measures; and

10. Any variation of, or alternative to, any of these measures.

EPA made it clear that this list was not to be considered comprehensive; in other words, states are free to devise control methods that do not appear on EPA's list.

The plan for each primary and secondary standard must show that the strategy adopted (i.e., the combination of all control measures) will result in the achievement of the standard within the required time.

The strategy must also be sufficient to maintain each standard in the face of "emission increases that can reasonably be expected to result from projected growth of population, industrial activity, motor vehicle traffic, or other factors that may cause or contribute to increased emissions."

Citizens will want to examine carefully the strategy proposed for their control region. Substantial reliance on only one method, such as emission limitations, may be insufficient even to maintain current levels of air quality. In such cases, citizens may want to insist that the plan contain provisions calling for additional measures, such as land-use and transportation controls. Later, of course, they will have to work with their state legislators to get these measures approved, but their inclusion in the plan is an important first step.

Compliance Schedules

Each major source of pollution within a control region must prepare and follow a detailed, step-by-step schedule of measures it will take to bring it into accord with the implementation plan. Such individual timetables are called compliance schedules. EPA requires the states to negotiate compliance schedules with all major sources of pollution. Once negotiated, such schedules become legally enforceable and are a part of the state's implementation plan. However, since such individual negotiations are bound to be slow, EPA did not require the inclusion of compliance schedules in the implementation plans due in January, 1972. Instead, EPA allowed the states an additional six months for the preparation of compliance schedules. By the end of that period, they must be submitted to EPA, together with the first semi-annual progress report that states are required to prepare. (See page 37.)

EPA further requires that any compliance schedule extending for 18 or more months contain provisions "for periodic increments of progress toward compliance." Citizens may want to urge state agencies to adopt similar regulations for compliance schedules covering lesser time periods. "Increments of progress" can take such forms as deciding upon abatement methods, letting bids for equipment or construction, signing contracts, or beginning installation of control equipment.

State agencies are prohibited from granting any variance or exemption from a compliance schedule if such a variance would prevent the attainment of any national standard by the required deadline. In our view, any request for a variance from a compliance schedule should be the subject of a public hearing if its granting could result in a continuing or significant degradation of a region's air. (See page 78 for suggestions regarding variances.)

Emergency Episode Procedures

In heavily polluted areas, consideration must be given to the emergency measures needed when the pollution level threatens to reach or exceed the danger point. Such occurrences are referred to euphemistically as "episodes," and they happen with some frequency in heavily urbanized or industrialized areas—usually as a result of heavy pollution and persistent climatic conditions. Without an effective procedure to contain or reverse an episode, it has within it the potential to produce severe health effects. Consequently, EPA regulations require that each Priority I control region formulate a contingency plan covering the emergency measures to be taken when there is a likelihood that pollution will reach levels that constitute "imminent and substantial endangerment to the health of persons." These danger levels were described in the *Federal Register* of October 23, 1971.

EPA's regulations include a suggested model plan for emergency episodes based on air quality data and meteorological factors. The first, or "alert", stage occurs when adverse meteorological conditions and pollutant concentrations approach levels at which preventive action becomes necessary. The second, or "warning", stage would be reached if the situation continues to deteriorate. The third stage—the "emergency" stage—occurs when air quality continues to "degrade toward a level of significant harm to the health of persons," thus requiring the fullest possible curtailment of contributing sources.

Each contingency plan is to specify the control measures to be taken at each stage, including legally enforceable control programs to be required of each stationary source emitting more than 100 tons of pollutants annually. Such control programs for individual sources must be submitted to EPA within one year after submission of a state's implementation plan. Moreover, the control measures must be aimed at curtailing in advance any single source that could trigger any stage of an emergency episode.

Depending upon the types of pollutants involved, such measures may include prohibitions or restrictions on motor vehicle traffic; curtailment of retail, commercial, manufacturing, or industrial activities; prohibitions and limitations on the use of incinerators, combustion of fuels, and burning of materials; and limitations on any other activity which may contribute to atmospheric pollution. In any state plan, the emphasis should be placed on *preventing* the occurrence of high pollutant concentrations, rather than on remedial actions. In other words, the reduction strategies applied during the early stages should be designed to prevent the occurrence of the next level. They should comprise an *action*, rather than a *reaction*, plan.

The contingency plans for emergency episodes must also include provisions for:

1. Acquisition of daily forecasts of atmospheric conditions during episodes;
2. Inspection of sources to ensure compliance with individual control requirements; and
3. Communication procedures for contacting public officials, major sources, and news media.

EPA does not require that contingency plans for Priority II regions be as detailed as the emergency episode contingency plan described above. But plans for Priority II regions must provide for at least a two-stage alert and warning system and for any necessary control measures (although curtailment programs for all major individual sources are not required).

Surveillance Systems

Both the Act and the EPA regulations require that state plans include two different surveillance systems—one for monitoring pollution levels in the ambient air, the other for monitoring emissions from individual sources, e.g., from each stack in a factory.

The *ambient surveillance system* must be fully completed and operating within two years of EPA's approval of a plan. EPA has established minimum requirements for such a system. For details, see the *Federal Register* of August 14, 1971.

EPA also requires that at least one sampling site in each control region be located in the area of estimated maximum concentration for each pollutant, that sampling schedules be described in the plan (along with the methods of data handling and analysis), and that the plan include a timetable for the installation of equipment to complete the system.

Citizens may want to inform themselves about the number and location of the sampling stations in their control region. Many state agencies have maps available that show these locations.

The *surveillance system for individual sources* has two components. First, EPA requires that all owners or operators of stationary sources maintain records and periodically report to the responsible state or local agency on the nature and amounts of their emissions. Second, the state agency must establish an inspection system to check on compliance by individual sources.

Obviously, since the requirement placed on the individual operator is essentially one for self-monitoring and reporting, it is imperative that the state set up a creditable system of inspection. State regulations usually specify the inspection procedures and tests to be used. In our view, these regulations should also require that owners or operators of sources permit access to any authorized official at reasonable hours for inspecting any facilities, equipment, or records. "Reasonable hours" should be defined as any time during operating hours. Inspections should be made with some frequency, and should be unannounced, with no published schedule. Records of each inspection and the findings, including raw emission data, should be available to the public.

Citizens might want to consider pressing for provisions that would require the control agency or the source to retain surveillance data (both ambient and emission source) for a minimum of three years.

We believe that state regulations should require sources to report promptly any significant breakdown, shutdown, or other failure of monitoring or control equipment. In the case of continuous or prolonged failure, the agency should have authority to require cutbacks, shutdowns, or other control measures.

Review of New Sources

EPA requires that each plan contain legally enforceable procedures that will enable the state agency to prevent the construction or modification of any stationary source that would interfere with attainment or maintenance of a national standard. EPA also requires that construction or modification be prevented if it will result in violations of any portion of an applicable control strategy. For instance, if a control strategy calls for reduction of sulfur oxides by all means possible, the state agency should be able to prohibit the construction of a new fossil-fuel power plant that would bring additional sulfur oxide pollution.

In addition, EPA requires that anyone who proposes to construct or modify a stationary source submit to the state agency information on the nature and amounts of expected emissions, the location, design, construction, and operations of such source, and any other information the agency may require in deciding whether to allow the proposed construction or modification.

Beyond this, EPA has left it to the states to work out their own procedures for controlling new or modified source emissions. In fact, there is no requirement that all control responsibilities rest with the state air pollution control agency. Citizens would therefore be well advised to scrutinize carefully any delegation of air pollution control authority to other state agencies. The delegated agency may find itself faced with a potential conflict of interest between the program it is routinely charged with advancing and the state's air quality program. For example, a public utilities commission may have difficulty giving much weight to the effect of a new power plant on air quality.

Neither the Act nor EPA requires states to have a formal permit system to control new sources. (For a brief discussion of permit systems, see page 46.)

Resources

Each plan must include a description of the manpower and funds needed to carry out the plan for five years. The description must include what is currently available, as well as projections of the additional resources needed at one-, three-, and five-year intervals.

Manpower needs include administrative, engineering, technical, and enforcement services. In a small agency, several of these roles may be filled by one person. Depending on the structure of the state institutions responsible for environmental services, some enforcement and management functions may be assigned to persons in other agencies, such as lawyers in the state attorney general's office. (See page 76 for further discussion of state government structures, and pages 73-76 for discussion of funding.)

Interstate Cooperation

Each plan must provide for the exchange of all necessary information among the responsible agencies in each control region whose boundaries lie in more than one state. All data on emissions, air quality, and control strategy development must be furnished upon request from one state to another. In addition, each state must provide for exchange of information on such factors as construction of new industrial plants, which may significantly affect air quality in any portion of another state or region.

When more than one state has jurisdiction over a given control region, EPA regulations require that each state involved give notice to the other affected states of any public hearings it is going to hold on implementation plans for that region.

And when agencies other than the state control agency are to have responsibility for carrying out any part of a plan, these agencies and the extent of their duties must be described in the state plan.

PUBLIC PARTICIPATION

Within the process of designing, adopting, and implementing a plan, there are important opportunities for the public to participate. These opportunities are specified within the Act, and the language of the Act, as well as its legislative history, make it clear that Congress intended the citizen to have an influential role in the air quality control process. Hearings held by the Senate Subcommittee on Air and Water Pollution, which drafted the bulk of the legislation, as well as public statements by subcommittee members, have emphasized the need for citizen involvement—not only because public support is necessary for good control programs, but because the determination of the nation's air quality is properly the right and responsibility of its citizens.

Public Hearings

The Act declares that public hearings *must* be held in each state before the state adopts an implementation plan and sends it on to EPA for approval. EPA's regulations require that each state:

1. Provide at least 30 days' notice of a hearing through "prominent advertisement" of the hearing's date, time, and place;
2. Make available for public inspection, in at least one location in each control region, the principal portions of the proposed plan for that region;
3. Make available for inspection all rules and regulations proposed for inclusion in the plan; and,
4. Keep hearing records that will contain, at a minimum, the list of those testifying, together with the text of each presentation.

A public hearing does not have to be held in each region covered by a proposed state plan. Hearings could be held, for instance, only in the state capital. Persons wishing to testify would have to travel to the capital or submit written testimony for the hearing record, in accordance with applicable state regulations. You may wish to press your state control officials and your governor to hold a public hearing in each control region. In addition, you may want to urge the agency control officials to adopt their own rules to make it easier for citizens to take part in the process. (See page 72 for suggestions.)

Each state may also choose to hold separate hearings on primary and secondary standards. But unless a separate hearing is

PUBLIC HEARINGS—WHY BOTHER?

Several considerations make a strong turnout of citizens at each public hearing a necessity. First, the attendance of large numbers of people who support strong plans and testify to this effect, however briefly, will help counter the arguments of those who claim that environmental concern is a passing fancy and that when the tough decisions come—as embodied in implementation plans, for example—most people just don't care. Second, the repeated testimony of citizens who praise the strong provisions of a plan and criticize its weaknesses will help to build a good hearing record. This is important because EPA must consider the hearing record when it decides whether to approve a plan or any of its portions. Also, if there are any legal challenges to the plan or to EPA's approval, the court will base its decision, at least in part, on the hearing record.

provided, implementation plans for primary and secondary standards must be considered at the same hearing.

States may choose to hold more than one hearing on the plan. They may, for example, hold separate hearings on different portions of the plan: one on regulations pertaining to sulfur oxides, one on those for particulate matter, one on emergency episode procedures, and so on. While it is easier to concentrate on one portion of a plan at a time, it is often difficult to attend a succession of hearings. In order to enable citizens to deal with the total plan as an integrated entity, however, you may want to urge your state to hold at least one hearing on the plan in its entirety.

Public Reporting

The Act recognizes the right of citizens to know what the air quality situation is in their respective regions. To this end, the Act and EPA require that states gather emission data from individual sources, correlate them with the standards established under the Act, and make all of this available to the public.

EPA also requires each state to submit quarterly reports on air quality and semi-annual reports on implementation progress. EPA does not require that the states make these reports available. But many state agencies already treat such reports as public information. Citizens in other states may want to press their state agencies to make such reports available—or at least summaries of such reports, if the reports themselves are lengthy and technical.

In developing portions of their plans, such as the control strategies and "emergency episode" procedures, state agencies are required to collect and analyze data on emissions from point sources and area sources.* EPA requires that such data and analyses be retained for its inspection, although it does not specify that such information must be made public. However, citizens may find this information valuable in evaluating state plans and may want to request that the state agency make it available.

PLAN APPROVAL

The state has nine months from the time EPA issues national ambient standards in which to devise and submit its implementation plan for EPA's approval. For the first six national standards, the process has already begun, and states have until January 30, 1972, in which to submit their respective plans.

At the conclusion of the nine-month period, EPA has four additional months (until May 30, 1972) to approve or disapprove each plan or any portion of it. To be approved, a plan must satisfy all the requirements of the Act, as well as the EPA regulations described in this chapter.

---

* "Point sources" are stationary sources emitting pollutants in amounts above specified levels (such as 25 tons per year), depending on their location and the processes used. "Area sources" are small, diffused individual pollutant sources such as automobiles, home or commercial heating units, and small home incinerators.

Under some circumstances, EPA is required to propose its own plan (or portion of one). This occurs when:

1. Any state fails to submit its own plan;
2. A submitted plan is judged by EPA to be inadequate; or when
3. A state fails to revise a plan satisfactorily within 60 days of notification to do so.

Within six months of proposing its own plan for a state, EPA must hold a public hearing and promulgate a final plan for that state. The plan then becomes effective for that state.

A record of the public hearing on the state implementation plan must accompany the state's submission to EPA. EPA is expected to review it, giving careful consideration to the public testimony. One thing citizens might do is ask the state to notify them of any changes made in an implementation plan after the hearing and before submission to EPA. Some states will provide written explanations of all such changes and make available to the public copies of the submitted plan, its justifications, and the hearing record.

If changes in a plan are made but not explained, or if the explanation appears to be unjustifiable, citizens can protest in writing to the EPA Administrator, citing relevant passages in the hearing record and other necessary arguments to support their protests. If EPA approves the plan, citizens may challenge the approval in the courts under the citizen-suit provisions of the Act. (See Chapter Seven.)

A state may ask EPA to determine the adequacy of a plan prior to final submission. When this happens, EPA's evaluation will be made available to the public upon request.

A more detailed description of the Act's provisions regarding implementation plans is included in the Natural Resources Defense Council's publication, *Action for Clean Air*. (See bibliography on page 92.)

REVISIONS AND EXTENSIONS OF THE PLAN

Even after EPA approval, an implementation plan is still subject to change. No air quality region is static. Each community grows or changes. And so, consequently, does the quality of its air. Also, new things are constantly being learned about the chemical composition of air pollution and its detrimental effects. As this new knowledge emerges, the national ambient standards may need revision, and new standards will require changes in the plans and procedures for implementation.

Revisions

There are three particular circumstances provided for in the Act under which an implementation plan must be revised:

1. To reflect changes in the national standards whenever these occur;
2. To take into account the availability of improved methods of achieving such standards (for instance, improvements in technology or applications of new control methods, such as emission taxes); and,
3. Whenever EPA finds that the plan is "substantially inadequate to attain or maintain the national standard which it implements."

The main initiative for revision lies with EPA, which must notify the state of any need to revise. Upon such notice, the state generally has 60 days to comply. However, EPA may extend the time after consultation with the state.

On the other hand, there is nothing to prevent a state from proposing its own revisions. Citizens may want to urge their state to include provisions in the plan for such state-inspired changes. Any such provision should be carefully worded to protect against a possible weakening of the plan's intent or effectiveness. All revisions, whether initiated by the state or by EPA, are subject to a public hearing, and all must have the final approval of EPA.

Extensions

The Act allows EPA to grant to the states three types of deadline extensions:

1. *Extension of a Primary Standard Deadline.* At the time a state submits its implementation plan to EPA for approval, the governor of that state may request EPA's permission to extend from three years to five the deadline for achieving the primary standards in control regions classified as Priority I. If the control region is an interstate area, the request is supposed to be submitted jointly with requests of the other governors who share responsibility for the region; if other governors do not intend to request such an extension, they must at least be notified of the request.

Any such request must be accompanied by a plan that will provide for the attainment of the standard within the extended period. The request must show that the necessary technology or other control measures required by the plan will not be available soon enough to permit attainment of the standard within the established three-year period. All sources which will be unable to comply must be clearly identified. All assumptions made about the time at which the controls will be available must also be identified and justified. Moreover, the plan must identify any alternative means of attaining the standard which were considered but rejected. Finally, the plan must require that all sources able to comply do so within the established three years and that the identified non-complying sources adopt specified reasonable interim control measures.

There is no specific requirement for a public hearing on a request for extension of the deadline for achieving a primary standard. Conceivably, a state could prepare and hold a hearing on a three-year plan, then propose to revise it to extend over five years —without a second hearing on the extension request.

2. *Postponement of Source Compliance.* The Act allows the governor of a state to request a one-year postponement in applying those parts of a plan that cover any stationary source or class of moving sources.* Such a request cannot be made until one year before those parts are scheduled to take effect. The request must include evidence that:

1. Efforts have been made, in good faith, to comply with such requirements as originally scheduled;
2. The source or class of sources is unable to comply because necessary technology or alternative measures are not yet available;
3. Available alternative measures have been or will be applied to reduce the impact of source emissions on health; and
4. The continued operation of the source is essential to national security or to public health and welfare.

A public hearing on such a request must be held before the proper EPA official. In interstate control regions, requirements for notifying the governors of other affected states are the same as those described on page 39.

But if postponement of an applicable portion of a plan will not prevent the attainment or maintenance of a national standard, the state does not have to make a formal request for extension under these provisions. In such a case, the postponement will be considered a plan revision and, as such, is subject to public hearing.

3. *Extension for Secondary Standard Plans.* If a state finds it difficult to prepare plans simultaneously for both primary and secondary standards, it may ask EPA for an 18-month extension of the deadline for submitting a plan to implement a secondary standard —but only for regions classified as Priority I or II. Any such request must show that attaining the secondary standard will require emission reductions beyond those which can be achieved through the "application of reasonably available control technology." In other words, the state must show that, given the present technology, there is no "reasonable" way of reaching the goal set by the

---

* This differs from a variance. A variance is usually requested by a source, whereas a postponement is requested by the government on behalf of a source or sources.

secondary standards. In interstate regions, requirements for notifying the governors of other affected states are the same as those on page 39. Finally, any such request must be made early enough to permit the development of a plan in time to meet the established deadline in case EPA refuses to grant the extension.

Citizens should ask their state agency to announce any intent to seek such an extension. If it does plan to seek an extension, its justification should be examined, with particular attention to its discussion of "reasonably available control technology." Has the agency, for instance, accepted without verification protests by pollution sources that technology is not available? What independent sources of information have been asked to evaluate such claims? Is applicable technology in use anywhere else? If so, why is it "reasonably available" there but not here?

If citizens feel that a state agency is seeking an extension that is not justified, they can write to the EPA Administrator, urging that the request be denied and explaining why.

If EPA grants such an extension, it means that only the timing is affected—not the standard. The plan must still provide for achievement of the national standard within a time specified by the state and accepted as "reasonable" by EPA.

5.
STANDARDS OF PERFORMANCE

"Standards of performance" are distinct from the ambient air quality standards discussed earlier. Whereas an ambient standard applies to the *total concentration of a pollutant in the atmosphere* from all sources, standards of performance constitute the maximum permissible emission levels for given pollutants *at their source*—if that source is among those included in a class of sources specifically designated by EPA as requiring such limitations.

Moreover, there are—or will be—two kinds of standards of performance set under the Act: *national* standards, which apply to "new and modified" sources within the categories of activity designated by EPA, and *state* standards, which apply to existing sources within those same categories of activity. In the case of both national and state standards of performance, it is up to EPA to designate—by category of pollution source—the kinds of facilities and processes that are subject to such emission limitations and then to prescribe what those limitations are.

This chapter discusses only those standards of performance which are set under the provisions of Section 111 of the Act. It should be kept in mind that many states (a) will have their own standards of performance for pollutants from processes which have not been designated by EPA and/or (b) will expand the standards set under the Act to apply to all sources which emit a specified pollutant (e.g., particulates).

NATIONAL STANDARDS OF PERFORMANCE (NEW AND MODIFIED SOURCES)

The Act requires EPA to establish national standards of performance for certain new and modified stationary pollution sources. These standards, the Act says, must reflect a "degree of limitation achievable through the application of the best system of emission reduction which (taking into account the cost of achieving such reduction) the Administrator determines has been adequately demonstrated." According to the Act, these standards are to be set for those types of pollution sources which EPA determines "may contribute significantly to air pollution which causes or contributes to the endangerment of public health or welfare."

Standards of performance are also called "new-source standards." The latter term can be misleading, however, since the Act says that those standards will also apply to existing sources which have undergone any "modification . . . which increases the amount of any air pollutant emitted by such source or which results in the emission of any air pollution not previously emitted." For example, a factory which installs equipment to produce a new product or to change the method of producing an old one would be considered "modified" under this definition, and the new-source standards would then be applicable.

EPA's initial list of the categories of major stationary sources subject to performance standards appeared in the March 31, 1971, *Federal Register*.

Here is the list:

1. Contact sulfuric acid plants;
2. Fossil-fuel-fired steam generators with heat inputs of more than 250 million BTUs per hour;
3. Incinerators of more than 2,000 pounds per hour charging rate (municipal-type refuse);
4. Nitric acid plants; and
5. Portland cement plants.

Other major stationary sources of pollution which will probably be included in future lists are foundries, smelters, chemical plants, and refineries.

The procedure works as follows:

Within 120 days of listing any category of stationary pollution sources, EPA must propose standards of performance for the different types and sizes of sources within that category. These regulations must be published in final form within 90 days after they are proposed. EPA has indicated that it probably will set aside 45 of the 90 days for receipt of comments and the rest for agency review and decision-making. The standards, when finally adopted, are applicable to any source that begins construction or modification after the date on which the standards were proposed. In the case of the categories listed above, that date was August 17, 1971.

The standards proposed for portland cement plants are presented below as an example of the form and content of such standards:

PORTLAND CEMENT PLANTS—Proposed Standards of Performance

Particulate matter

(1) 0.30 pounds from the kiln per ton of feed to the kiln.

(2) 0.10 pounds from the clinker cooler per ton of feed to the kiln.

(3) Visible emissions from the kiln shall not exceed No. ½ Ringelmann (10% opacity).

(4) There shall be no visible emissions from all other sources within the plant.

It is important that citizens attempt to comment on such proposals in the future. To facilitate review and analysis of the proposals by interested parties, EPA intends to publish a brief explanation of the factors considered by the agency in arriving at the proposals, including a description of (uncontrolled) emissions from the source in question, a justification of the proposals, a brief discussion of economic impacts, and selected references. This information has been published for the first five categories mentioned above in a booklet called ***Background Information for Proposed New-Source Performance Standards***.

Despite such helpful materials, laymen will have difficulties in analyzing such technical proposals. To help with such problems, many clean-air organizations have established technical advisory committees.

Since standards of performance usually take the form of direct emission limits, citizens may wish to obtain copies of emission regulations adopted by state or local agencies which have earned good reputations for strong air pollution control programs. In our opinion, the states of Maryland and New Jersey and the cities of New York (new code) and Los Angeles are good examples. Copies of state regulations can be purchased from the Commerce Clearing House (see page 95 for address). Comparison of the federal proposals with these state and local regulations may suggest that stricter standards are possible and confirm the existence of better control methods.

Any state may develop and submit for EPA approval a procedure for implementing and enforcing new-source performance standards after EPA has set up guidelines for the states to follow. EPA has the authority to enforce these standards, but it may delegate this authority to any state which submits an adequate plan. (There is, of course, one exception: EPA retains enforcement authority over new sources belonging to the federal government.)

EPA ON STANDARDS OF PERFORMANCE

"It should be noted that the proposed [national] standards do not necessarily represent the ultimate in emission control. Performance standards are limited by the requirement that they reflect 'adequately demonstrated' technology and consideration of cost factors; in addition, it is clear from the legislative history that the techniques needed for compliance must be reasonably available to affected persons. Because many State laws do not impose such limitations, some States already have adopted and are enforcing emission limitations more restrictive than the proposed performance standards. For example, New Jersey's sulfur oxides control regulations require the use of fuels of extremely low sulfur content, which are available in relatively limited quantities; alternatively, polluters can employ stack gas cleaning techniques, but they would have to be capable of higher efficiency than any that have been 'adequately demonstrated' thus far. Accordingly, there will be instances where State standards are (and, if necessary for attainment and maintenance of the national ambient air standard, should be) more restrictive than EPA's new-source performance standards."

EPA Memorandum, July 22, 1971

Whenever it delegates this authority to a state, EPA does not relinquish its own right to enforce standards if that becomes necessary.

STATE STANDARDS OF PERFORMANCE (EXISTING SOURCES)

New and modified sources, however, do not produce the lion's share of pollution in the designated categories. Existing sources do. And here the Act provides a new and particularly useful tool. It requires EPA to prescribe regulations under which states must set emission standards for pollutants from existing sources in each category for which a performance standard would apply if the source were new or modified. If a state fails to develop or enforce such standards for existing sources after EPA has promulgated regulations requiring them, EPA itself can develop and enforce them.

Because of the demanding deadlines imposed on the states for submitting implementation plans for the six national ambient standards already established, EPA decided to defer the prescription of regulations for state performance standards until after submission of the implementation plans for ambient standards in January, 1972. It is now likely that they will be published in early 1972. Citizens may wish to urge EPA to publish its regulations quickly, in keeping with the clear intent of the Act, so that pollutants not covered by national ambient or by hazardous air pollutant standards may be brought under state control as soon as possible.

PERMIT SYSTEMS

EPA's final regulations for standards of performance may or may not require a permit system for new and existing sources. Even if EPA does not require this, citizens may decide that their state agencies should adopt a systematic approach along these lines.

For example, the owner or operator of a new source might first be required to obtain a permit for construction—after satisfying the public and state air quality officials that the proposed facility will not prevent attainment of the ambient standards and that it will meet all applicable emission limitations. After construction (or modification, in the case of an existing source), a permit might then be required before the facility could begin operation. All such permits could be revocable upon showing of failure to comply. Revocation or suspension might require a shutdown or curtailment of operations until compliance is assured.

In some circumstances, a similar system of operating permits for existing sources might be desirable in order to achieve the timetables of a compliance schedule. Such a system might call for temporary permits for brief periods while abatement equipment is being installed according to a time schedule approved by the agency. Regular permits would be granted upon completion of necessary control steps, possibly subject to renewal after a set date, upon a showing by the applicant of consistent compliance over the previous period of operation.

6.

HAZARDOUS AIR POLLUTANT STANDARDS

At sufficiently high levels, almost any pollutant will cause illness or death. But some substances pose a much more immediate threat. Generally, these are substances which build up in the body over periods of time. Thus, even small amounts can be dangerous. Asbestos, beryllium, cadmium, and mercury are among these dangerous pollutants. As scientific knowledge increases, more substances may be found dangerous enough to be classified as hazardous pollutants.

While writing the Act, Congress was urged to set "zero emission levels" for these hazardous air pollutants. Such legislation was deemed impractical, however. First of all, traces of these elements exist in natural forms and are sometimes naturally present in the atmosphere. Second, many common human activities yield minute amounts of these substances. The burning of most fossil fuels, for instance, results in the release of trace amounts of mercury.

The Act directs EPA to set an emission standard that "provides an ample margin of safety to protect the public health" for each pollutant which, in EPA's judgment, "may cause, or contribute to, an increase in mortality or in serious irreversible, or incapacitating reversible, illness." The choice of the word "ample" should be noted: other standards under the Act are required to include only "adequate" margins of safety.

EPA's first hazardous-substance list names three pollutants: asbestos, beryllium, and mercury. Proposed standards for these were published in the *Federal Register* of December 7, 1971. Thus, final standards must be promulgated within 180 days of the original proposal, i.e., by June 4, 1972.

The list of hazardous pollutants must be revised "from time to time." The same timetable applies for each addition to the list: standards must be proposed within 180 days of listing; a public hearing must be held within 30 days after proposal; and the final standards must be promulgated within 180 days. There is no requirement that the list of hazardous pollutants be updated according to any definite schedule.

At the public hearings, persons representing the affected interests may be expected to raise questions about the levels at which danger occurs. But since these pollutants are generally retained by the body and tend to build up in it, it can be argued that any exposure above levels already occurring from natural causes is deleterious and that emission standards should be set at the lowest levels possible.

In the case of stationary sources about to be built or modified, hazardous-pollutant standards become effective immediately upon proposal. EPA has authority to prohibit the construction or modification of any source which will not comply with promulgated standards. Obviously, some type of reporting or permit system will be necessary to enforce this provision.

Existing sources must comply within 90 days of the date when final standards are promulgated. EPA is authorized to grant a waiver for a period of up to two years for an existing source only if two conditions apply: first, if a waiver period is necessary for the installation of controls; and second, if steps are to be taken during the period "to assure that the health of persons will be protected from imminent endangerment." Since many of these hazardous substances cause no discernible immediate effects from small exposures, it may be difficult to prove "imminent endangerment." Although the law does not provide for the extension of any waiver beyond the two-year period, it does state that the absence of control technology is, in itself, a basis for exemption.

Under the law, the President may exempt any source from compliance for an initial period of two years if he finds that control technology is unavailable and that operation of the source "is required for reasons of national security." The President must report each exemption to Congress. Citizens might want to ask their Congressmen to request full disclosure to Congress of information regarding each exemption.

Finally, the Act allows each state to develop its own procedure for implementing and enforcing hazardous-pollutant emission standards. As was the case with new-source performance standards, EPA will probably draw up guidelines for the states to follow in developing their plans. Here, too, EPA will probably wait to publish these guidelines until after the states have submitted their implementation plans for the national ambient air quality standards. Guidelines for state plans regulating emission of hazardous air pollutants are expected from EPA in early 1972.

7.

AUTO EMISSION CONTROLS

The automobile is the nation's number one polluter. By weight, more than half of all the nation's man-made air pollution can be attributed to the internal combustion engine. In some urban areas, it reaches as high as 85 per cent of the total. Its exhausts include deadly carbon monoxide and such major contributors to smog as hydrocarbons and nitrogen oxides. The automobile emits varying amounts of lead, asbestos, and other pollutants, many of which end up in the lungs.

INDIVIDUAL CONTRIBUTIONS TO CONTROL

Unfortunately, at least in regard to air quality, life in America is heavily dependent upon the automobile. There is some sign that this may be changing, but the country is so deeply committed to the automobile—economically and culturally—that significant change is certain to be slow. In the meantime, there are things that the individual can do to help abate auto emissions. Individuals can:

1. Use public transportation whenever possible;
2. Use car pools and bicycles—and walk;
3. Maintain a car in optimum emission-reducing condition;
4. Use good driving habits, avoiding unnecessary emission-producing maneuvers;

5. Convert ordinary gasoline-powered engines to other low-pollution fuels; and

6. Buy cars with the lowest levels of emissions.

The importance of individual action for reduction of automobile emissions cannot be discounted. It has been estimated that auto-caused air pollution levels in many major metropolitan areas could be cut by as much as 30 percent if the measures listed above were widely used.

Wider availability and use of public transportation is one of the major solutions to vehicular air pollution. Unfortunately for many Americans, it must be counted among the long-term solutions. The decay of public transit has left many of us without much choice—we either drive or we don't travel. And many—the poor, the aged, the very young, the handicapped, rural residents, non-drivers—just don't go. We have to face the fact: we are not going to get clean air without some ambitious improvements in public transportation systems. Clean air and efficient public transportation go together. (Those who are interested in pursuing this issue can refer to the bibliography on page 93 for further information and can contact the organizations listed on page 95.)

When it is necessary to drive, we can make sure our cars contribute as little as possible to pollution levels. Proper adjustments and maintenance can reduce emissions well below average.* For those who do not service their own cars, one problem has been finding a mechanic who knows how to reduce emissions. This should become easier in the future. Beginning with the 1973 model year, EPA will require all auto manufacturers to furnish detailed emission-reducing tune-up specifications for each new car. With these instructions, any competent mechanic should be able to make the proper adjustments.

Lead has long been added to gasoline because it is the cheapest way to raise the octane level (anti-knock quality) of gasoline. But many car owners use much higher octane than is necessary, thus wasting money while polluting the air . . . ALWAYS USE THE LOWEST OCTANE, LOWEST LEAD FUEL THAT KEEPS YOUR CAR FROM KNOCKING.

—Eco-Tips No. 2, CONCERN, Inc.

Drive well. Avoid rapid acceleration, screeching halts, jerky speed-up-slow-down patterns, weaving in and out of traffic. All these maneuvers increase emissions. The lowest levels are achieved by steady, easy driving patterns. Where possible, plan travel hours to avoid heavy traffic.

---

* Cars built during and after model year 1968 can be adjusted by setting certain screws according to the manufacturer's specifications. In cars built during and after the model year 1970, those specifications can be found under the hood.

If you live in an area where alternative low-polluting fuels are available, take advantage of them. Costs of converting an ordinary gasoline-powered engine to a system that utilizes liquefied natural gas or propane are initially high: from $400 to $700. But some of this investment can be made up through savings on fuels; almost all of the alternative fuels are cheaper than gasoline. Unfortunately, these fuels are not widely available, so cars equipped with these systems must generally retain the capacity to run on regular gasoline.

When you buy a car, purchase one that produces low emission levels. Ask the salesman about the car's federal certification and about proper maintenance for the emission control devices. It is not always true that smaller models or foreign 4-cylinder cars emit less pollution than bigger ones. But the smaller cars do consume less fuel and thus afford a minor resource savings.

PROVISIONS OF THE ACT

As important as these individual initiatives are, they are still only palliative. The real problem is with the internal combustion engine itself. Before we can have clean air in many metropolitan areas, the engine will have to undergo some dramatic alterations.

In recognition of this, the 1970 Clean Air Amendments required EPA to set emission standards for any class of new motor vehicles emitting air pollutants dangerous to public health or welfare. Congress itself established such standards for the three most prevalent auto pollutants: carbon monoxide, hydrocarbons, and nitrogen oxides. By 1975, levels of the first two must be reduced to no more than ten per cent of the 1970 partially controlled levels. By 1976, nitrogen oxide emissions must be reduced to no more than ten per cent of the 1971 uncontrolled levels. These standards must be met by each model during its "useful life," which the law has defined as "five years or 50,000 miles, whichever comes first."

On June 30, 1971, EPA announced the numerical equivalents of the required reductions. The 1970 standards permitted emissions of 34 grams of carbon monoxide per vehicle mile (gm/mi). The 1975 standards will allow 3.4 gm/mi. Hydrocarbon limits were set at 4.1 gm/mi; the 1975 levels will be .41 gm/mi. There were no 1970 standards for nitrogen oxides; 1976 levels will be .4 gm/mi, down from 1970 average emissions of 4.0 gm/mi. (For nitrogen oxides, EPA has also set an interim standard of 3.0 gm/mi, effective with 1973 models.)

The law allows auto manufacturers to ask EPA for one-year extensions of the 1975 and 1976 deadlines. Such a request cannot be made until January, 1972, in the case of carbon monoxide and hydrocarbon standards or until January, 1973, for nitrogen oxide standards. Within 60 days of receiving such a request, EPA must rule on it. Within this time, the agency must hold a public hearing and determine whether:

1. Such extension is essential to the public interest or the public health or welfare of the U.S.;
2. All good faith efforts to meet the standards have been made;
3. The applicant has established that effective control technology is not available or has not been for long enough to be applied; and,
4. Studies by the National Academy of Sciences and other information available to EPA indicate that such technology is not available.

EPA is only authorized to grant a single one-year extension for each of the standard deadlines. If the auto manufacturers obtain this first extension and still want additional time, they must request it of Congress.

Assuming that Detroit meets the '75 and '76 standards (with or without the one-year extensions), how reliable will the control devices be? It is not fair to prejudge, but emissions from 1970 models have not generally achieved the required levels of control even when mileage is low and normal maintenance has been provided.

As reported in the *Washington Post* on August 29, 1971:

> . . . a seven-city survey of 1,600 privately driven 1970 models, averaging 9,000 miles use, found them exceeding their carbon monoxide ceilings by 100 percent and their hydrocarbon ceilings by 50 percent. EPA scientists do not know why these 1970s showed such poor results, but theorize that ignition and stalling problems prompted owners to take their cars in for adjustments that distorted the performance of emission controls, which rely on a retarded spark and a lean fuel-air mixture.

For the first time, the 1970 amendments authorize the agency to test assembly-line models and to require the manufacturers to do such testing. The Act prohibits manufacturers or dealers from selling non-complying vehicles and from removing or making inoperable any control device. Penalties for violation of this section are as high as $10,000 for each offense.

EPA is required to publish in the *Federal Register* the results of emissions tests performed on prototype and assembly-line models of all makes of new cars. Regional EPA offices can help get copies of the test results. Citizens can consult the results before purchasing new cars.

Beginning with 1971 models, manufacturers were required to include in their new car warranties a guarantee that the car complies with applicable emission regulations and that it is free from defects in materials or workmanship that would cause any noncompliance during its useful life. But since a car's "useful life" is presumed to have ended after it has gone 50,000 miles or is five years old, it is obvious that the federal requirement does not cover many of the cars on the road today. Thus older cars are subject only to whatever controls (if any) the individual states may choose to establish.

The Act provides that—after workable tests have been developed to check on the performance of control devices—EPA must require auto manufacturers to revise their warranties. These new warranties will require manufacturers to replace at their own expense any faulty control device if, during the useful life of a car:

1. The faulty device was maintained and operated in accordance with the manufacturer's instructions;

2. Failure of the device results in the owner being penalized (penalties would include the loss of right to operate the car, fines, and so on).

Detroit wants permission to require the motorist to service the emission system frequently. The more service required, however, the more likely that motorists simply won't bother. The companies will then be relieved of free adjustment of the device, because the motorist failed to maintain it in proper order.

The companies argue they are unable to provide an emission-control system that will work with very little servicing. But Congress's aim, in imposing the performance warranty, was to lay the economic burden of repair on the manufacturers and thereby induce them to design a virtually trouble-free system.

Spencer Rich, "Detroit: Cleaning Up," *The Washington Post*, August 29, 1971

Fuels and Additives

Under previous laws, the federal government has had the discretionary authority to register all motor vehicle fuels and additives. The Clean Air Amendments expand this authority by prescribing the information to be provided by the manufacturer in the registration process. It is up to EPA to decide whether to require the kind of registration newly authorized by the Act. If it does require it, then each manufacturer of a fuel or additive must provide EPA with the name and trade name, the concentration, purposes, and chemical composition of such products. Non-registered materials could not then be sold.

The Amendments also authorize EPA to require additive manufacturers to conduct tests to determine potential effects on public health and to describe techniques for detection and measurement. After reviewing all relevant information, EPA could restrict or prohibit any fuel or additive which it believes will endanger public health or welfare or significantly impair the performance of emission control devices. EPA has already announced its intention of requiring a reduction in the amount of lead in gasoline to .5 grams per gallon by 1974. Lead, widely used to boost the octane (power) rating of gas, not only endangers health, but spoils the performance of the catalytic afterburner (exhaust control device) which many auto manufacturers apparently hope to use to reduce emissions from 1975 cars.

Low-Emission Vehicles

The law establishes a federal program for the purchase of special low-emission vehicles for government use, once they are developed. EPA is also authorized to provide financial assistance to developers of such vehicles. This program may help alleviate the concerns of manufacturers who have correctly pointed out the risks of developing experimental low-emission vehicles in the absence of a guaranteed market.

Citizens may decide to urge their state and municipal governments to adopt purchase requirements consistent with the federal provisions. After the federal certification and purchasing program has aided the development of such vehicles, state purchases can help expand the market. The city of Boston has already announced its plan to convert all city-owned cars to run on liquefied natural gas (LNG). Since the costs of fuel and maintenance for LNG vehicles are lower than those for ordinary cars, Boston hopes to recover much of its initial changeover investment, while reducing city pollution levels in the bargain.

STATE RESPONSIBILITIES FOR AUTO EMISSION CONTROL

Although the Act specifically prohibits states (except California) from setting their own emission standards for *new* vehicles, the states retain the right to control emissions from *other* vehicles. This poses a number of problems, such as establishing inspection and enforcement provisions, determining cost-benefit ratios, and developing control strategies and alternate transportation methods.

Auto emission standards—or any other regulations—are only as good as their enforcement. And enforcement may be next to impossible without a practical, reliable inspection system. Many states already have some kind of automobile safety inspection system. Citizens in such states may want to consider adding emission inspection to existing safety check programs.

There are several factors to be examined before advocating adoption of such a system. One is the availability of simple and reliable testing equipment. Many of the existing emission testing systems involve complicated devices and procedures, and the test results can be affected by a number of factors, including altitude, humidity, or operator's skill. And some of the simpler tests are misleading because they measure emissions only under certain conditions, such as idling speeds, which do not take into account actual driving results. Several practical and reportedly accurate testing systems are in the prototype stage, but some of these may prove expensive.

Expense is a second factor to be weighed carefully. Will the cost of establishing and maintaining an emission inspection system be proportionate to the expected benefits? The initial outlay for a statewide system can easily run to several million dollars, and operating costs (such as salaries and record-keeping) can add substantially more. What kind of reduction in pollution levels can be expected from such an investment?

Some results of a few experimental programs indicate that reductions from emission-inspection programs may be disappointing. There are several reasons for this. It is often difficult to get proper repairs for cars which have failed an emissions test. One survey showed that about 30 per cent of cars which were rejected for high emission levels were tuned up, then retested, and failed the second test. Another problem is that, for many cars, an adjustment might be required every two months, whereas inspections in most states might occur only once or twice a year. A third problem is the tendency of some motorists to avoid inspections if they feel their chances of doing so without being caught or heavily penalized are good. Some of the measures necessary for controlling emissions—such as retarding the spark or decreasing the richness of the fuel mixture—may cut down on mileage per gallon or on performance characteristics like acceleration. Some drivers will find this undesirable and may attempt to meet control requirements by adjusting their cars properly to pass the test and then readjusting them between tests. All of these factors affect the level of emission reductions resulting from an inspection program.

Another problem to be considered is the operational difficulty of administering an inspection system. Population distribution, distances between urban centers, meteorological conditions, and the relative amounts of pollution from automotive sources vary widely. For instance, large, sparsely populated states may find the disparity between the costs and benefits of a state inspection system too great to justify its establishment. Such areas may decide to depend on the degree of emission control achieved through federal regulation of new models. On the other hand, desire to maintain pristine air quality and visibility in some unpolluted areas, particularly in the West, may dictate a strict state control program, even where there is little urbanization.

Some alternate control strategies should also be evaluated. While a state inspection system focuses on the individual motorist's care of his car, other methods can be used to lower the total number of miles driven or limit the location of use. These methods include reduction of highway construction, restriction on driving in certain urbanized areas, taxes on mileage or on gasoline, taxes on emission levels, and development and support (including financial subsidies) of public transportation systems in urban and rural areas.

Before advocating the adoption of any one method or combination of methods, citizens may want to do further research on the advantages and problems of each. One place to start is with two studies done for EPA by the Institute of Public Administration. These are *Governmental Approaches to Air Pollution Control* and *Governmental Approaches to Automobile Air Pollution Control*. While a number of readers may not accept some of their assumptions—one, for example, puts great stock in the notion that the construction of urban freeways will reduce auto pollution—both studies present interesting discussions of the economic and administrative dimensions of different control strategies. (See bibliography, page 91.)

The Act also authorizes EPA to pay up to two-thirds of the costs of developing and maintaining state auto emission and control inspection systems. For states that want these systems, despite dubious cost-benefit ratios, any federal assistance will be a boon.

The most thorough emission inspection system in any state is being installed by New Jersey in a cooperative experiment with the federal government. There will be three sets of standards: one for pre-1968 models, one for 1968 and 1969 models, and a third for 1970 and later models. At least one-third of the state's registered 3.3 million cars are expected to fail the initial annual tests. The failure rate may rise in 1973, when even tougher standards are planned. Cars which fail the test will be prohibited from operating. Windshield stickers will indicate compliance. The heaviest burden may well fall on lower-income car owners who usually drive the older and less-cared-for problem cars and generally have few alternative methods of transportation to jobs, schools, and shopping. Officials expect that the program will reduce carbon monoxide levels by 20 percent in the first year, and hydrocarbons by 32 percent. Citizens may wish to evaluate the New Jersey program when planning control methods for their own states.

8.

THE CITIZEN'S LEGAL RIGHTS

Recent trends indicate that litigation will be used more and more as a means of protecting environmental interests. This chapter discusses briefly the opportunities for litigation presented by the 1970 Clean Air Amendments and by several other laws.

CLEAN AIR AMENDMENTS

The 1970 Amendments specifically recognize the right of citizens to bring suit against any violator of standards or other requirements of the Act. Any "person" may sue any other "person" for failure to enforce or comply as required. "Person" is defined as "an individual, corporation, partnership, association, State, municipality, or political subdivision of a State."

But the Act imposes two restrictions on the right to sue the government. No one may sue the federal government—EPA—for non-performance of any action that lies within EPA's discretionary authority, i.e., an action not specifically *required* by the Act. And "any other governmental instrumentality or agency" may be sued only "to the extent permitted by the Eleventh Amendment to the Constitution." (The Eleventh Amendment prohibits the federal government from permitting citizens to proceed against their own state except in certain circumstances. This prohibition has been interpreted differently by the various states and by the ten U.S. Circuit Courts, each of which has jurisdiction over a certain bloc of states. Citizens should consult their own state constitutions and court rulings to determine how this restriction affects them.)

Any person intending to bring suit must give 60 days' notice to:

1. The Administrator of EPA;
2. The state in which the alleged violation occurs; and
3. The alleged violator.

However, in the case of an alleged violation of a hazardous-pollutant standard or of any enforcement order issued by EPA, suit may be brought immediately upon giving notice, without the 60-day waiting period. Citizens filing such suits may want to include a petition for a temporary restraining order or a preliminary injunction.

Citizens may not bring suit against alleged violators to force compliance with a standard or other provision of the amendments if EPA or the state "has commenced and is diligently prosecuting" the violation. But citizens may "intervene"—i.e., file supporting suits or ask to be recognized as a co-plaintiff—in such a federal or state suit. Conversely, EPA may also intervene in any suit brought by citizens or a state.

The Act authorizes any court to award any costs of litigation, "including reasonable attorney and expert witness fees," to any party to a suit, as the court thinks appropriate. This provision may help to remove one of the common deterrents to litigation by private citizens—expense.

Yet legal action can be costly, particularly in pollution cases where the collection and presentation of technical evidence is often necessary.

Also, courts may require plaintiffs to post a bond; that is, a specified amount of money (or equivalent security) in accordance with the Federal Rules of Civil Procedure. Bonds are required for various reasons. They can be used simply to discourage suits, on the theory that a plaintiff having a poor case or bringing suit for frivolous or harassing purposes would be deterred by the prospect of bond forfeiture if the case were decided against him. Bonds can sometimes be awarded to the defendant to reimburse him for losses incurred as a result of the suit or of related causes, such as loss of income during the period of an injunction.

The Act places no restriction on any right to sue or to seek other relief under any other law. Citizens who wish to employ nuisance laws against polluters, for example, may do so. Such suits under other laws may be necessary for offenses not yet covered under the Act. However, suing under the Act has distinct advantages. For instance, the issue of a person's "standing" (or right to sue) does not occur. In the past, environmental suits have been challenged or dismissed on grounds that citizen plaintiffs lacked proper "standing." The Act specifically avoids such questions of standing by providing that "any person may commence a civil action on his own behalf. . . ."

The Department of Justice will usually represent EPA in any litigation involving the agency. However, if the department does not notify EPA "within a reasonable time" that it will act on the agency's behalf, then the EPA Administrator may appoint other attorneys to act. This provision makes it more difficult for interagency and political conflicts to delay or circumvent action by EPA. Citizens may find it desirable to urge the inclusion of similar provisions in their state laws.

In legal proceedings related to implementation plans and auto emission controls, the Administrator of EPA is empowered to issue subpoenas to compel the attendance and testimony of witnesses and the production of relevant papers and data. Owners or operators of pollution sources are required to furnish all information requested by the Administrator. All such information is to be considered public with one exception—information classified as a "trade secret." Upon satisfactory showing by the sources that disclosure would "divulge trade secrets or secret processes," EPA must treat such information as confidential. But emission data are specifically exempted from protection as a trade secret. If making emission data public will reveal a manufacturer's trade secrets, his only recourse is to clean up the emissions. In no case, according to the Act, may emission data be treated as confidential.

Any person or organization that wants to sue EPA over the promulgation of any national ambient standard, any new-source standard of performance, or any hazardous-pollutant standard can file such a suit only in one court, the United States Court of Appeals for the District of Columbia in Washington, D.C. Such a suit must be filed within 30 days of the date of promulgation of the disputed standard; suits filed after that time are permitted only if the grounds on which the suit is based have arisen after the 30-day period. This provision is intended to prevent the common legal tactic of delaying indefinitely the effective date of a regulation. To further assure that no tactic of delay by legal challenge will occur in implementing standards, the Act specifically prohibits judicial review of standards during the course of enforcement proceedings in court.

Persons wishing to challenge EPA's approval of any state implementation plan for national ambient standards or for new-source performance standards may do so in the federal court for the district in which they reside. Again, such a legal challenge must be filed within 30 days after such EPA approval, unless the grounds for the suit arise at a later time. This provision makes it easier—geographically, at least—for citizens and polluters in a given control region to challenge the plan for that region.

The Act also allows EPA to request the Attorney General to order mandatory licensing of any patent needed to achieve compliance with any new-source performance standard, hazardous-pollutant standard, or auto-emission standard. EPA and the Attorney General must first determine that there are no reasonable alternative methods to the patent device or process in question and that unavailability of the patent right may result in a substantial lessening of competition or a tendency to create a monopoly. The Attorney General may then ask for a ruling on the conditions under which the patent will be issued. (He would seek this in the U.S. District Court in whose jurisdiction the patent holder resides.)

TWO OTHER FEDERAL ACTS

In addition to the Act, there are two other recent major laws that provide helpful legal tools to persons attempting to clean up the country's air. One is the National Environmental Policy Act of 1970; the other is the 1966 Freedom of Information Act. Some aspects of both are discussed briefly below.

National Environmental Policy Act

One of the most significant provisions of the National Environmental Policy Act (NEPA), Public Law 91-190, is the requirement that federal agencies file "environmental impact statements." These statements, which are submitted to the President's Council on Environmental Quality, must detail any major proposed action that might affect the environment. Known informally as "102 statements" after the section of NEPA that established this procedure, they must discuss the environmental consequences (both certain and potential) of the proposed action, ways to minimize the damages, and alternative courses of action. If the environmental harm caused by any contemplated action is great enough, conceivably the action could be prohibited. In most cases, however, the statements serve as working tools to ensure that environmental impacts are considered and that damages are minimized in every way possible.

In spite of a great many uncertainties in regard to interpretation and application of the impact-statement provision, it has already served as the basis for some notable environmental protection victories. One of the most recent and significant was a Court of Appeals decision that ordered the Atomic Energy Commission (AEC) to take into consideration all environmental aspects of nuclear power plant construction, including disposal of radioactive wastes. The Court ruled that previous AEC impact statements had "made a mockery" of the Act by their superficiality. As a result, the AEC is now revising its regulations for the construction of nuclear power plants. The Court's findings heartened many environmentalists. Although the decision applied only to the AEC, it may give impetus to efforts to force other federal agencies into more than token compliance.

Another important provision of NEPA is its explicit recognition of the citizen's right to a decent environment. As mentioned earlier in this chapter, the problem of lacking standing or the right to sue in certain cases has often prevented suits against polluters by private citizens. NEPA may help remove the lack of standing by its declaration that "The Congress recognizes that each person should enjoy a healthful environment and that each person has a responsibility to contribute to the preservation and enrichment of the environment." Several state legislatures have passed or are considering laws similar to NEPA, as mentioned on page 63.

The Freedom of Information Act

Finding out what is going on within a federal agency is not always easy. Citizens trying to get the facts on some situation are often frustrated and confused by bureaucratic obfuscation and delay.

To help the public find out what their government is up to, Congress passed the Freedom of Information Act in 1966. This Act reaffirms the public's right of access to federal government information with few exceptions (such as information required by Presidential order to be kept secret in the interests of national security, trade secrets, personnel and medical files). All federal agencies must make available all records properly requested under the provisions of this Act. If an Agency withholds such records, the person may bring suit in federal court for their release. In the court proceedings, "the burden is on the agency to sustain its action." If the agency does not comply with the court's order to furnish the records, the court may punish the responsible employees for contempt. Proceedings brought before a court under this Act take precedence on the court docket and must be heard and ruled on as soon as possible.

An excellent guide to the Freedom of Information Act has been published by the Washington Institute for Quality Education. It is primarily designed for lawyers, but several parts are useful to the layman, especially the suggested form for requesting information under its provisions. (See page 92 for further information.)

TELEVISION, RADIO, AND THE "FAIRNESS DOCTRINE"

The "fairness doctrine" developed by the Federal Communications Commission (FCC) requires radio and television broadcasters to present both sides of controversial public issues. For example, clean-air advocates may find it possible to secure broadcasting time to rebut certain kinds of programming or advertising with information about auto pollution or alternative modes of transportation.

The Citizens Communications Center, a small non-profit public-interest organization, will try to help citizens who are attempting to invoke the fairness doctrine in their dealings with local broadcasters and the FCC. The Center has recently published a progress report detailing some of its activities and some of the services it offers. (See page 95 for the address.)

Another step in the direction of providing more accurate information to the public has been taken by the Federal Trade Commission (FTC). The FTC has announced [illegible] it intends to make advertisers document claims that a product is "better," "improved," "cleaner," or "ecologically sound." The Commission hopes to close at least part of the gap between claim and fact. The frequency and number of citizen complaints about misleading advertising will probably help the Commission to pursue this on an even larger scale. (See page 94 for the FTC address.)

LEGAL RESOURCES ON THE STATE LEVEL

Other legal resources for citizens to investigate include the state constitution, municipal charters, laws establishing the various agencies and their responsibilities, administrative and procedural codes and customs and, of course, the state and municipal pollution control regulations. Copies of these can often be found in libraries or obtained from state agencies or state legislators. Make—or better yet, have a lawyer make—a thorough analysis of these regulations.

We believe that the law should provide for both civil and criminal penalties for pollution violations. Civil offenses are sometimes easier to prove, since conviction generally requires "a preponderance of the evidence," whereas criminal convictions require proof "beyond a reasonable doubt."

It may be advisable to obtain copies of regulations from states or municipalities which have earned good reputations for adopting strong pollution control laws, as suggested on page 44, and compare them to your own. You will find that the best enforcement provisions are worded to allow *preventive* action. The weaker ones allow action only *after* damage has occurred.

Several states are presently considering legislation somewhat similar to the National Environmental Policy Act. In 1970, Michigan adopted a landmark law, the Environmental Policy Act, that will probably serve as a model for many other states. The Michigan act specifically allows any person to bring suit to protect the state's air, water, and other natural resources. *Governmental Approaches to Air Pollution Control*, a study done for EPA by the Institute of Public Administration, contains a discussion of some of the merits of the Michigan law and some potential problems in carrying it out. It also provides a good overall view of the advantages and drawbacks of private legal action to control pollution, including an explanation of "standing" problems and other legal traditions that are sometimes unclear to non-lawyers. The references alone are valuable. (See page 91 for further information.)

In several states, an "environmental strike force," a team of lawyers working solely on enforcing pollution control regulations, has been established in the state attorney general's office or in the state environment protection agency. Some municipalities are also considering similar moves.

ASSISTANCE FROM NATIONAL LEGAL ORGANIZATIONS

A number of public interest law firms specializing in environmental litigation have appeared around the country. Citizens living near a university law school or in major metropolitan centers may discover such firms in their own area. One of these firms which has announced its intention of specializing in legal action for air quality is the Natural Resources Defense Council (NRDC). NRDC has set up a "Project on Clean Air" to monitor the federal government's carrying out of the Act. The Project assists citizens around the country in working with EPA and their state agencies and in taking legal action where necessary. The Project is publishing several citizen guides to particular sections of the Act and other relevant laws; a guide on implementation plans is available now. (See page 92.) NRDC also publishes a periodic newsletter and is establishing around the country a network of "cooperating attorneys" who will give citizens on-the-spot help with legal problems in the environmental field. (See page 95 for the NRDC address.)

9.

ECONOMIC CONSIDERATIONS

It is not within the scope of this booklet to make a detailed exploration of the complexity of economic restraints and incentives surrounding the air pollution control problems. But economics is such a fundamental part of the air pollution control picture that this handbook would be remiss if it did not address briefly some of the economic implications of cleaning up the air.

No one denies that controlling air pollution will be costly. What is too often overlooked, however, is the fact that pollution itself has its price. As noted in Chapter One, air pollution costs billions each year in damages to vegetation, materials, and human health. Because economics is not an exact science and because of the difficulty in measuring specific impacts of pollution in dollar terms, many of these costs are unquantified. But common sense can tell us that pollution-related illness causes drops in job productivity, loss of wages due to absenteeism, increases in health insurance and family welfare benefits, and a general decline in what we call the "quality of life."

It helps, too, to put the costs of air pollution control into historical social perspective. After all, such comparatively recent developments as child labor laws, job health and safety standards, minimum wage requirements, a shorter work week, and social security are now widely recognized as major contributions to our "quality of life." They have raised the American standard of living —a standard that is being questioned for its emphasis on consumption but not for its basic premise that all citizens have the right to pursue a decent, healthy, satisfactory life. In this context, air pollution control is a new social requirement that can be fitted into the economic and social system of the country without major hardship or displacement.

But as an advocate for clean air, you will be confronted by some very strong arguments that compliance with the air quality standards will force shutdowns, throw hundreds out of work, and jeopardize the economic stability of the community. The implication, if not the outright assertion, will be that you and your fellow advocates for clean air hold the community's continued prosperity in your hands. The canard—"what do you want, jobs or clean air?"—will be repeated many times, and you will find yourself accused of being an environmental absolutist who is callous toward the financial consequences for your fellow citizens. This is not a comfortable spot to be in. But if you find yourself in this embattled position, there are some things to remember.

First, take a hard look at an industry which is threatening to shut down a plant. If changes in plant facilities and operations to meet the emission standards are really too costly, then the industry most likely has a totally antiquated plant. Chances are that it will have to make drastic changes in plant and equipment anyway, just to maintain a competitive position in its particular market. The air pollution control requirements will simply hasten this transformation. On the other hand, if the plant is so antiquated that the company has no intention of modernizing, it is likely that plans for closing it already exist. Pollution control requirements will, at most, hasten the closure. Industries in such a precarious position are often beset by management problems and are glad to have an external fall guy on which to pin the blame.

Look, too, at the plant's niche in the production structure. Is it a part of a much larger industrial complex? If so, the plant may have some strategic role to perform in the industry's production cycle, and the industry will want it continued. Installation of pollution control equipment in such a plant will be a relatively small consideration in terms of the industry's total operation.

When an industry threatens to move, remember that plant location is determined for a number of reasons: access to markets and raw materials; availability of labor, transportation, energy supply; tax structure; and—increasingly—good schools and pleasant surroundings for its employees. An industry that finds these factors suitable in its present location is not likely to go shopping for a new location where pollution control requirements will be less stringent. Besides, the existence now of national standards limits the mobility of an industry in seeking a site where there is greater freedom to pollute.

Some companies may use the threat of job cutbacks to encourage a more dilatory approach to control. Again, take a careful look at such threats. Try to ascertain the exact number of jobs involved, the nature of those jobs, the way in which pollution controls will affect the jobs, and what alternatives exist, including the prospect of new jobs that would be created in controlling the plant's pollution. When there is little substance to cutback threats, the company can earn a very poor public image by such tactics.

In some instances, however, pollution control requirements will provide the push which sends a marginal plant over the edge. In such cases, clean-air advocates will have to weigh their alternatives very carefully. If few jobs are involved, or if new jobs for the affected workers are available, the plant may well be closed without a disporportionate hardship to the community. But in economically depressed areas, the community may well prefer pollution to unemployment, and other measures—such as proportionately stricter controls on other sources in the area—may have to be adopted.

Eventually, some kind of worker protection provisions may be necessary. The president of the United Auto Workers Union, for instance, has proposed federal legislation that would severely penalize companies for using economic blackmail. This legislation would guarantee job training, relocation and/or employment benefits—paid by the company, not the government—in the event of control-related layoffs or shutdowns. Another bill would provide federal financial and technical assistance (when justified) for conversion of a plant to a non-polluting operation and for payments to workers during the period of conversion.

In discussing control expenses with industry, it is advisable to seek a breakdown of the overall costs of installing and operating control equipment into unit costs. How much will the overall costs —when spread out over the life of the equipment and discounted for tax purposes and recoverable resources—be reflected in the unit cost of production? What may seem to be an enormous initial investment in capital equipment and operating costs often averages out to only a slight increase in the per-unit cost.

Another thing to keep in mind is that a number of economic incentive schemes have been developed to encourage business and industry to make the needed clean-up investment. Modest federal programs that supply loans and other direct financial assistance are available to certain industries in certain locations. Most such programs are administered by agencies other than EPA, such as regional economic development commissions. (For information on the availability of such assistance locally, we suggest that citizens ask their Congressmen, state economic development department, or their Chamber of Commerce.)

A far more important form of incentive, however, is the tax relief available through write-offs or credits to industries that make a capital investment in pollution control equipment. Such concessions allow a portion of the costs of pollution control to be recovered by special deductions from normal after-profit taxes or by accelerated depreciation that allows certain control costs to be spread over a five-year period.

One drawback of the write-off method deserves special attention. Existing subsidy and tax-credit systems are largely directed toward the installation of "add-on" equipment to control pollution.* When pollution-control equipment recovers its own costs—by sale of reclaimed by-products or by fees paid to owners for shared use by other pollution sources—tax write-offs may not be taken. (The write-off regulations may be found in the *Federal Register* of May 16 and May 24, 1971.)

Unfortunately, the addition of such equipment to a production process may be the costliest and least efficient way to reduce pollution. In many cases, changes in raw materials or in production methods could result in far superior pollution control, as well as in higher productivity. Existing regulations, however, encourage sources to invest in control equipment in hopes of recovering part of the expenses; there is no compensation for the use of alternate methods, such as process changes.

A second drawback of incentive methods is their limited helpfulness to firms making low profits. These firms can be financially strained by even moderate abatement costs. The relief afforded them through a tax credit can be almost non-existent, since the firm's poor earnings mean that its taxes are already low. Tax write-offs and investment credits are generally useful only to firms with good profit margins, and it may be argued that these are least in need of government help.

Finally, it should be kept in mind that what the government loses in revenues from one source must be made up from others. If tax income from industry is lessened through expansion of incentives, the tax burden on individual private incomes will be greater.

Most states now have tax-incentive programs. Any state department of revenue or taxation should have a copy of the applicable regulations. In addition, the National Association of Manufacturers has compiled a state-by-state listing of these laws. (See page 95 for NAM address.)

Sources of Economic Information

It is clear that carrying out the Act and the related state air quality programs will demand an increasing economic sophistication on the part of citizens, control officials, and legislators. Read-

---

* To qualify for rapid tax write-offs under current regulations, a "building" must be devoted exclusively to pollution control, whereas a "facility" can perform other functions as well—with the percentage of the costs to be written off subject to determination by EPA.

EMISSION TAXES

Increasing consideration is being given to the adoption of taxes on emissions in order to encourage abatement. Bills providing for such charges have been introduced in the U.S. Congress and in several state legislatures. Under this approach, a source would be free to select the most efficient method—add-on equipment, process changes, different raw materials—to reduce its pollution levels. Theoretically, sources that find abatement relatively inexpensive would prefer a maximum degree of clean-up to the payment of taxes, whereas sources that find thorough controls expensive or difficult would tend to reduce their emissions only to levels at which tax payments would be economically preferable to the institution of more effective control measures.

The effectiveness of this approach presumes, of course, that the taxes will be set high enough to make abatement attractive. The approach also raises a number of difficult questions. How, for example, should the rates be set? Should small, long-existing sources be taxed at the same rate as large newer ones? Although any increase in the price of a product due to abatement costs will simply reflect the true cost to society of that product, should certain goods considered desirable to society be taxed at favorable rates?

When sophisticated monitoring equipment is lacking or too expensive, should taxes be figured, not on actual emissions, but on "surrogates" (substitutes)? For example, a sulfur oxides tax could be assessed on the percentage of sulfur in a fuel. If the source has installed control equipment with an efficiency of 95 percent, then 95 percent of the tax could be rebated.

If the emission-tax concept is adopted, we believe that it would be advisable to experiment on a small scale, with careful evaluation of its effectiveness and of expected and unexpected results. For example, a high tax on urban parking might be adopted in order to reduce the amount of auto exhausts. Will the parking tax significantly cut commuter traffic or will it simply increase tax revenues with no appreciable reduction in pollution levels?

Should emission taxes go into general revenues or into special funds earmarked for pollution control? If such taxes are put into general funds, those taxed may attempt to sue on grounds that the purpose of the tax is to raise revenues and that it is therefore arbitrary and discriminatory. If such taxes are placed in special funds, then it might be argued that they are not primarily revenue measures. But establishing special funds also has drawbacks. Creation of earmarked funds with a guaranteed income over long periods has, in the past, resulted in the growth of independently financed bureaucracies over which the public has little or no control. If creation of a special fund is considered necessary, we believe it should be liquidated at the end of its originally determined period. Further, we believe it inadvisable to use such earmarked funds as the basic financing of control programs. The level of program financing should be based on program needs, not on taxes collected from the controlled sources.

ers interested in learning more about economic factors would do well to start with a study called *Governmental Approaches to Air Pollution Control*, already mentioned on pages 57 and 91.

Industry itself can be one of the best sources of information about cost problems. Accurate information often may be difficult to obtain, but it can be very valuable in helping citizens to understand the cost problems as seen by business. Such categories of information include the initial (capital) costs of a control system, the maintenance and operating costs, comparisons of these control costs with other expenditures (including advertising and public relations budgets), the ways in which the costs will affect the consumers, and alternate methods of control.

An excellent source of data on control costs for specific industries is the EPA report to Congress, *The Economics of Clean Air*, published in March, 1971. The report, which will be updated and expanded annually, surveys current and projected federal and state control programs and their impacts on mobile and stationary pollution sources. The current report discusses the costs of emission controls for solid-waste disposal programs, for heating and power plants, for 17 selected industries (including gray iron foundries, iron and steel mills, petroleum refineries, and rubber plants), and the total impact of these control costs on U.S. price structures. The summary notes, for instance, that, in seven of the 17 industries studied, costs will be met primarily by passing them on to the consumer through price increases (which will be approximately two and one-half percent). Three industries will recover enough valuable materials to offset the entire annual cost of controls. Seven industries "will probably have to absorb all or part of the control costs, which will reduce their revenue from sales, taxes paid, and net profits." These seven industries can recover some—but not all—of the control costs through increased prices. (See page 92 for further information.)

Another source of economic data on control costs is the Council on Economic Priorities (CEP). The Council, a non-profit organization, utilizes Wall Street securities-analysis techniques in its research into the social implications of corporate policies and practices. It issues periodic reports on specific industries. A recent study on the paper and pulp industry, for instance, details control practices and spending levels for each of the major companies. A report on electric utilities is currently being prepared. Subscriptions to CEP reports may be expensive for individuals, but libraries and business firms may have them. Specific studies may be purchased individually from CEP. Several reports have been issued in paperback-book form by commercial publishers. (See page 95 for the CEP address.)

10.

THE CITIZEN'S ROLE IN POLICY-MAKING

In addition to the opportunities for citizen participation and initiative noted in earlier chapters, there are some broader policy areas that affect the clean air process and deserve public attention and involvement. This chapter discusses three such areas: public information, pollution control funding, and governmental structure.

PUBLIC INFORMATION

The Act specifically recognizes the public's right to information about certain air pollution control matters. Both the Act and EPA's regulations for implementation plans require that the public be allowed access to all emission data. EPA officials have also indicated their intention of making available to the public, on request, much of the information submitted to EPA by the states, including the quarterly and semi-annual progress reports. Moreover, most states have "freedom of information" acts of their own, which define the citizens' right to know certain matters under the jurisdiction of state agencies, including the air pollution control agency (See page 92.)

But this is not enough. Unless the states take an active role in informing the public, the interested citizen will have a hard time finding out what is going on. One basic step that many state control agencies can and do take is to maintain mailing lists of interested individuals and groups who ask to receive regular reports on agency activities and on matters affecting air quality.

The Illinois Pollution Control Board, for instance, puts out a newsletter twice a month. A typical issue includes summaries of all Board meetings and decisions during the preceding two weeks, the results of all variance requests acted upon, schedules of public hearings on all pend[illegible]ts and on all proposed regulations. The newsletter also ca[illegible] explanations of all proposals. One issue contained a special 22-page report by the chairman, detailing the Board's first year of activities, analyzing the accomplishments, listing the problems and suggesting ways of dealing with them.

As another example, the State of Maryland takes particular care to see that public hearings on all proposed regulations are publicized widely. It usually mails hundreds of notices throughout the state about six weeks in advance of any hearing, along with the texts of regulations to be considered, directions for reaching the hearing site, and instructions on how to submit comments for the hearing record.

BASIC INFORMATION YOUR AGENCY CAN PROVIDE

1. The quarterly, semi-annual, or annual ambient monitoring data for all pollutants (not just those covered by national standards), with high, low, and average levels noted for each sampling site.
2. Explanations of trends in pollutant levels for the past six months and forecasts for the coming period, including changes in the region, such as the establishment of important new sources.
3. Descriptions of enforcement proceedings, including compliance orders, court proceedings, permit grants and revocations.
4. Descriptions of all variances requested and granted.
5. Annual detailed budget and expenditure reports, including manpower needs and projected costs.

PUBLIC HEARING PROCEDURES

The need for *timely* information about public hearings cannot be emphasized too strongly. The federal requirements for implementation plan hearings were discussed on page 36. In addition, most state administrative codes set some minimum requirements for public hearing procedures, and most agencies have the latitude to prescribe additional procedures. The following list suggests some good procedures which you may want your agency to adopt.

1. Proposals to be considered at hearings should be made available sufficiently in advance to allow time for thorough analysis. As a general rule, 30 to 60 days should suffice. This will vary according to the complexity and implications of a proposal.

2. At least 30 days' notice should be given for each hearing; each notice of hearing should include instructions for obtaining copies of the proposals; notice should be widely given through major newspapers, television and radio stations, and mailings to interested individuals and organizations.

3. Revisions of proposals between the time of issuance and the hearing date should be avoided. Where significant revisions prove necessary, announcement of this should be made and the hearing rescheduled to allow adequate evaluation of the new proposals.

4. Fair and uniform procedures regarding the order of speakers and the time limits should be followed at all hearings. Ideally, everyone wishing to testify should be given a chance. When time limits and the number of prospective witnesses prevent this, special care should be taken to solicit written comments for the hearing record from those unable to testify orally.

5. When it serves the convenience of prospective witnesses, daytime hearings should be supplemented with evening sessions.

6. In general, any interested person should be permitted to question any witness, providing that advance written notice of the intent to do so has been given.*

7. Full transcripts should be made for each hearing and should be available for public examination and copying.

8. Agency decisions handed down after hearings should be accompanied by a written explanation of the decision.

FUNDING

Citizens have a right to expect good performance from their control agencies; they have a corresponding responsibility to help the agency do its job. Public information programs, adequate manpower, monitoring systems, record-keeping, and enforcement activities all cost money. Citizens will have to help their agencies obtain it.

The question then becomes: where does the money come from, and how much is enough? Until 1963, when federal funds first became available, air control programs were largely dependent on municipal taxes. Even in 1970, local funds supplied over 60 percent of local program budget totals.** As pollution control becomes mandatory throughout the country, control costs to local government may well increase.

* Environmentalists have succeeded in getting this provision adopted in New Mexico. They have successfully utilized it in formal hearing procedures to bring out relevant points overlooked by, or unknown to, state officials.

** This percentage is somewhat misleading in that local spending greatly outstripped federal in heavily populated states with major urban concentrations, such as California, Illinois and New York. Local expenditures in such states amounted to millions more than the federal contributions.

FUNDING AND MANPOWER FOR STATE AND LOCAL AIR POLLUTION CONTROL AGENCIES, 1970-71

(In thousands of dollars)

State	Fiscal year 1970 funding			Fiscal year 1971 budgeted [1]			Fiscal year	
	Federal	State and local [2]	Total	Federal	State and local	Total	1970 man-years	1971 man-years
Alabama	15	156	171	15	169	184	10	12
Alaska	54	21	75	54	23	77	5	6
Arizona	314	243	557	314	382	696	48	47
Arkansas	49	44	93	60	49	109	4	10
California	2,069	7,665	9,734	2,463	10,114	12,577	614	635
Colorado	567	560	1,127	611	636	1,247	71	74
Connecticut	407	272	679	448	484	932	48	56
Delaware	249	148	397	197	172	369	26	31
District of Columbia	213	107	320	234	117	351	21	21
Florida	488	658	1,146	961	734	1,695	90	123
Georgia	316	192	508	358	344	702	35	65
Hawaii	0	73	73	0	205	205	7	14
Idaho	46	37	83	47	38	85	6	2
Illinois	1,391	3,477	4,868	1,255	2,831	4,086	212	291
Indiana	380	454	834	323	580	903	61	71
Iowa	87	86	173	92	180	272	9	29
Kansas	127	61	188	141	94	235	29	31
Kentucky	341	393	734	534	529	1,063	54	76
Louisiana	120	106	226	154	182	336	15	16
Maine	54	27	81	36	18	54	2	6
Maryland	1,307	899	2,206	1,426	910	2,336	124	173
Massachusetts	415	324	739	575	436	1,011	33	61
Michigan	1,336	662	1,998	1,331	956	2,287	59	116
Minnesota	346	231	577	350	369	719	42	46
Mississippi	44	23	67	46	24	70	3	6
Missouri	733	583	1,316	761	598	1,359	104	107
Montana	106	85	191	131	97	228	10	17
Nebraska	30	15	45	90	46	136	3	8
Nevada	148	130	278	159	136	295	22	26
New Hampshire	32	34	66	45	38	83	6	7
New Jersey	788	796	1,584	1,430	1,323	2,753	149	177
New Mexico	78	67	165	217	148	365	11	23
New York	2,332	7,876	10,208	2,629	8,784	11,413	628	720
North Carolina	454	246	700	578	396	974	55	81
North Dakota	15	13	28	15	12	27	3	2
Ohio	30	1,754	1,784	904	1,422	2,326	84	129
Oklahoma	90	84	174	105	114	219	13	21
Oregon	557	420	977	547	524	1,071	55	57
Pennsylvania	1,958	1,641	3,599	2,604	2,424	5,028	204	295
Rhode Island	114	66	180	83	42	125	8	12
South Carolina	224	166	390	295	359	654	23	44
South Dakota	0	0	0	14	7	21	0	3
Tennessee	503	259	762	788	416	1,204	58	100
Texas	1,139	693	1,832	1,475	960	2,435	155	182
Utah	123	80	203	99	122	221	12	17
Vermont	21	15	36	53	26	79	3	6
Virginia	231	146	377	320	306	626	34	42
Washington	1,222	981	2,203	1,212	1,246	2,458	93	85
West Virginia	138	110	248	221	226	447	14	27
Wisconsin	57	34	91	100	137	237	7	14
Wyoming	16	9	25	26	14	40	3	4
Guam	0	0	0	9	7	16	0	1
Puerto Rico	144	108	252	141	104	245	25	25
Virgin Islands	30	16	46	39	20	59	4	4
Total	**22,748**	**32,666**	**55,414**	**27,115**	**[4] 40,630**	**67,745**	**3,414**	**4,256**

[1] Data represent activities of air quality agencies, not expenditures for pollution control facilities. Most States follow the Federal July–June fiscal year, although some use the calendar year or another 12-month period.

[2] Data for State and local agencies are substantially complete although they include only agencies receiving Federal financial assistance.

[3] 19.19 percent increase over 1970 level.

[4] 24.38 percent increase over 1970 level.

[5] 24.69 percent increase over 1970 level.

Source: Environmental Protection Agency, Office of Air Programs.

Table taken from Environmental Quality, Second Annual Report of the Council on Environmental Quality, pp. 74-75.

State programs, like local programs, have depended on federal funds in the majority of states. With the new Act, the costs of state control programs can be expected to rise even more steeply than the costs of local programs, since the Act places the main control responsibilities on the states. The burden on state revenues cannot be eased by merging or dropping programs, as it can be with local programs.

Will there be a corresponding increase in federal contributions in order to lighten the state burdens? A major provision of the Act authorizes the federal government to contribute up to 75 per cent of the cost of establishing a statewide or regional (within one state) agency and up to 60 per cent of the maintenance costs in succeeding years. For interstate agencies—i.e., single agencies having jurisdiction over areas in two or more states—the federal contribution may amount to 100 percent of the establishment costs for the first two years and up to 75 per cent of the operating costs thereafter. For EPA's major air pollution control activities—including grants to states—the Act authorizes $125 million for 1971. The authorization rises to $225 million in 1972 and $300 million in 1973.

While theoretically such federal cost-sharing provisions seem to solve the problems of financing state agencies, in practice they may not. One problem is the "money gap": that is, the difference between the amount *authorized* in the legislation and the amount later *appropriated* by Congress. This "gap" between authorization and appropriation, a chronic problem with the federal funding of air and water pollution control programs, has resulted in a considerable slowing down of the whole control process.

Since the amounts ultimately appropriated are allocated to states according to federal formulas, it is quite possible that few established state agencies will receive the maximum permissible share of 60 per cent of maintenance costs. The federal formulas themselves can become quite intricate. The general rule is that each state must receive something (the exact amount is determined by EPA). Beyond that, there is a good deal of fluidity, although such factors as population distribution within a given EPA region, previous state funding levels, "need" as measured by a variety of considerations, and, of course, the influence of Congressmen and governors are all involved.

Citizens should find out as much as they can about EPA's allocation formulas to get a better idea of how their state is doing. A first step is to determine how much of the state agency program is eligible for federal support, using any criteria or restrictions found in the allocation formulas. For example, a motor vehicle inspection system may be part of a state program, but it may only qualify for special, separate funding. If 90 per cent of the state program is eligible, remember that the state must pay not only for all of the remaining 10 per cent but also for *at least* 25 per cent of the portions that are eligible for federal support. Thus, for a 90 per cent eligible program costing a total of $100,000, the state would pay $10,000 for the non-eligible portion, plus a minimum of $22,500. The other $77,500 could be provided by the federal government—but this is rare indeed.

EPA is developing some guidelines to indicate what funding levels are adequate for state agency programs. One outdated figure, based on requirements of the 1967 law, indicated that an annual expenditure of 25 cents per capita would be the minimum. The new figure will probably be considerably higher.

GOVERNMENT STRUCTURE

Aside from the problem of adequate funding, one of the big questions for the citizen interested in clean air is whether the control agency is effectively organized and managed. Citizens and officials in many states have increasingly realized that, even with good laws and adequate budgets, an archaic state governmental structure is incapable of dealing effectively with environmental problems. In a number of states, this realization has led to restructuring of environmental programs and responsibility.

In some states, this has taken the form of a reorganization, with environmental control programs consolidated in one existing department. In others (New York, Massachusetts, and Illinois, for example), a new department or super-agency has been created to oversee all environmental programs. The Illinois system is described below, not because it is "best"—the best is whatever works most effectively—but to give an idea of how one state went about improving its governmental pollution control machinery.

Illinois created three new environmental structures: a Pollution Control Board, an Environmental Protection Agency, and an Institute for Environmental Quality. Each has specific responsibilities in various fields of environmental management: air, water, noise, and solid waste. The functions of each dovetail with the other two. The Pollution Control Board has the major policy-making responsibility. It is charged with setting standards, granting variances, and acting as a first or lower court in enforcement proceedings. (Appeals from the Board's decisions go directly to the State Court of Appeals, not to the lower courts.) The state Environmental Protection Agency is the enforcement arm; it handles the technical work, issues permits, and is responsible for monitoring. The Institute for Environmental Quality is a research unit which advises the Board and the Agency and is responsible for long-range planning.

The structure of the Board has drawn the most attention. The

Board has five full-time members, who are assisted by a permanent staff. Board members are salaried and are appointed by the Governor for three-year terms. They must disclose their finances and are expected to be financially independent of any of the interests over which they have authority. They must posssess professional background relevant to their duties.

Other states have taken different courses. An excellent analysis of different state structures and of the advantages and pitfalls of each can be found in *Managing the Environment: Nine States Look for New Answers*, a study completed in April, 1971, by Elizabeth Haskell of the Woodrow Wilson International Center for Scholars in Washington, D.C. (See page 92 of the bibliography.)

Whether or not a state government reorganizes its environmental protection and control structures, there are two things a citizen would do well to scrutinize his agency for: the composition of the control board and the policies governing the granting of variances (exemptions for specific sources from specific regulations for specific periods of time).

In 1969, the *New York Times* surveyed the membership patterns of state and municipal control boards, which are generally charged with responsibility for standard-setting and for granting exemptions from standards. On October 19 of that year, the *Times* said: "Industries and other polluters such as municipalities still wield great influence, opposing or weakening regulatory laws and 'packing' regulatory boards with their own spokesmen." The control boards were often dominated by producers of pollution, the *Times* reported, and enforcement usually suffered as a result.

THE NEW ALABAMA CONTROL BOARD

. . . The law . . . provides for a seven-man commission with broad authorization to adopt regulations to control air pollution. The commission will be chaired by the state health officer and the other six members, appointed by the governor, will include a licensed physician qualified in respiratory diseases, one registered professional engineer experienced in air pollution control and four representatives of the public. No member may be an employee, officer, or significant stockholder of any corporation which holds a permit from the air pollution control division.

Air & Water News, September 6, 1971

One reason control board membership is so important is that, in most states, the board has the authority to grant variances or exemptions from state regulations. In the past, it has not been uncommon for boards to give automatic approval of a variance request. Often the public was unaware that a variance had been requested or granted. Where hearings were required, these were often *pro forma* proceedings, conducted with little or no notice. In some states, hearings have even been closed to the public.

As a matter of policy, we believe that the burden of proof in variance proceedings should fall on the applicant: that is, he should have to prove his need for an exemption—the public should not have to prove that the request lacks merit. A citizen can easily check his state's administrative code or agency regulations with regard to policy and practices. Model variance codes provide:

1. That each variance request be subject to public hearing.

2. That applications for variance be submitted on forms provided by the board or agency. Such forms should require essential information such as an exact description of the location and facility for which the request is made; the justification for the request; predicted emissions of each pollutant during the period of the variance; estimates of the damages inflicted on the community by such emissions; description of interim measures to be taken to minimize such damages; the previous compliance record of the source; a suggested schedule of compliance to be observed, with specific dates for completion of each stage and justifications for each date.

3. That the duration of any variance be limited to a maximum of one year and that any second application demonstrate adherence to the compliance schedule imposed under the first variance.

4. That the board be authorized to insist on the posting of a bond (for example, in cases where a source's previous compliance record has been poor), with possible forfeiture for failure to comply. The bond should be set high enough to provide a strong incentive for meeting any compliance schedule imposed.

5. That the board have authority to impose additional conditions, such as the clean-up of other facilities operated by the same source.

6. That the board must
—give adequate public notice of a hearing, with simultaneous availability of all information provided by the applicant; and
—make its decision within a specified period of time. Such a limit (for example, 120 days) should allow sufficient time for the board to review the application, to establish a hearing date and give adequate notice, to hold the hearing, and to deliberate the decision. Any variance application not granted within the statutory time limit should be deemed to be denied.

7. That any interested party may question an applicant at any hearing, if written notification of his intent to question is given to the board by 4 p.m. of the preceding business day.

8. That the board be empowered to issue a temporary order to cease any emissions above applicable standards while a variance application is pending.

9. That appeals from board rulings go to the state Court of Appeals.

Since the granting of variances plays a major role in determining the speed with which desired air quality goals will be reached, citizens should follow variance proceedings closely. Public attendance at hearings is essential, particularly when a major pollution source is requesting a variance. Variance rulings are essentially political decisions; thus public pressure and publicity can help to assure that these decisions are environmentally sound.

A SUMMING UP

We now have relatively strong federal legislation to assist state and local air quality control efforts. As this booklet was being prepared, implementation plans for the first national air quality standards were being formulated. They will soon be put into force throughout the country. The air quality control process provides an opportunity to bring emissions from point and mobile sources under control; to firmly establish enforcement procedures; to assist effective citizen participation in policy-making; and to stimulate changes in other important aspects of society, such as land-use patterns, population density, and transportation systems.

With all this: Will we get clean air, and can we keep it clean? It all depends . . .

- on appointed government officials at all levels, on their integrity and their commitment to the goals;
- on elected federal and state legislators and city councilmen, on their grasp of the problem and their willingness to serve the public interest;
- on society generally, the people as a whole, on their values and system of ethics and priorities, and their willingness to sacrifice certain short-term conveniences for the long-term public good;

Most of all, it depends on *you*, the citizen, on your understanding of what is at stake, on your vision of a quality life, and on your dedication to shaping it. Because you now know more about the problems and the potential solutions than most people, you can accept the responsibility of citizenship by participating more fully and by involving others in the processes that will determine the quality of the air you breathe.

APPENDIX

GLOSSARY

The following glossary is not intended to be comprehensive or highly technical. It includes several terms which, though not used in this manual, often appear in other materials on air pollution control.

Air quality control region—see pages 16 and 27.

Air quality criteria—the levels of pollution and lengths of exposure at which, based on currently available scientific information, specific adverse effects on health and welfare are known to occur. These are delineated by EPA in "criteria documents."

Ambient air—the unconfined space occupied by the atmosphere; i.e., outdoor air. See: troposphere.

Ambient air quality standard—a limit on the amount of a given pollutant which will be permitted in the ambient air:
—long-term standard—typically a limit for one year for a given pollutant. It is usually expressed as an annual geometric mean or arithmetic mean.
—short-term standard—a limit for a short period of time for a given pollutant, such as one day, three hours, and so on.
—primary standard—a limit for a given pollutant that, according to the Act, is to be set by EPA at a level stringent enough to protect the public health.
—secondary standard—a limit for a given pollutant that, according to the Act, is to be set by EPA at a level stringent enough to protect the public welfare.

Anti-degradation clause—a provision in air quality standards that prohibits deterioration of air quality in areas where the pollution levels are presently below those allowed by the standards.

Area source—small, diffused individual pollutant sources such as automobiles, home or commercial heating units, small home incinerators.

Arithmetic mean—the sum of a given number of factors divided by the number of factors, e.g., $3+4+5+6 = 18 \div 4 = 4.5$. Arithmetic means tend to be higher than geometric means.

Background level—amounts of pollutants present in the ambient air due to natural sources. Examples: marsh gases, pollen.

BTU (British Thermal Unit)—the amount of heat needed to raise the temperature of one pound of water one degree Fahrenheit.

Carbon monoxide (CO)—a colorless, odorless, very toxic gas produced by any process that involves the incomplete combustion of carbon-containing substances such as coal, oil, gasoline and natural gas.

Carcinogenic—cancer-producing.

Chilling effect—phenomenon in which the increase in atmospheric particulates inhibits penetration of the sun's energy, thus gradually lowering the temperature of the earth.

Coh—abbreviation for "coefficient of haze," a unit for the measurement of visibility interference.

Compliance schedule—a legally enforceable detailed timetable of actions to be taken by a pollution source to bring it into accord with implementation plans or other regulations.

Control strategy—the combination of measures (such as emission limitations, land-use plans, emission taxes) designed to reduce levels of a specific pollutant in the ambient air.

Control techniques—methods, equipment and devices applicable to the prevention and control of air pollutants at their sources, such as process changes, flue gas stack devices, stack height requirements, fuel use limitations, plant location rules, and so on. They are described in EPA's control-techniques documents.

Ecosphere—the layer of earth and troposphere inhabited by (or suitable for the existence of) living organisms.

Effluent—an outflow; a discharge or emission of a liquid or gas.

Electrostatic precipitator—a device that uses electrical (rather than mechanical or chemical) attraction to collect particulates for measurement, analysis or control.

Emergency episode—an air pollution incident in a given area caused by a concentration of atmospheric pollution reacting to meteorological conditions (e.g., an extensive inversion) that results in a significant increase in illnesses or deaths.

Emission inventory—a list of air pollutants emitted into the atmosphere of a given area in amounts (usually tons) per day, by type of source.

Emission standard—the maximum amount of a pollutant that is permitted to be discharged from a single source.

Epidemiology—the study of diseases as they affect populations rather than individuals. It includes the distribution and incidence of diseases; mortality and morbidity rates; and the relationship of climate, age, sex, race, income, job, smoking habits, and other factors.

Fossil fuels—coal, oil, and natural gas; so-called because they are the remains of ancient plant and animal life.

Geometric mean—the Nth root of the product of N factors (N = number of factors), e.g., $3 \times 4 \times 5 \times 6 = \sqrt[4]{360} = 4.35+$. Geometric means are often lower than arithmetic means.

Greenhouse effect—the phenomenon in which the sun's energy, in the form of light waves, passes through the atmosphere and is absorbed by the earth, which then radiates the energy as heat waves that the air is able to absorb. The air thus behaves like glass in a greenhouse, allowing the passage of light while trapping heat.

Hazardous air pollutant—defined by the Act as a pollutant which, in EPA's judgment, "may cause, or contribute to, an increase in mortality or in serious irreversible, or incapacitating reversible, illness." These pollutants include asbestos, beryllium, cadmium, and mercury.

Heating season—the coldest months of the year, during which pollution levels are higher because of increased consumption of fossil fuels.

High-volume sampler—also called a Hi-Vol. A device used in the measurement and analysis of suspended particulate pollution.

Hydrocarbons—any of a vast family of compounds originating in materials containing carbon and hydrogen in various combinations. Some may be carcinogenic; other are active participants in photochemical processes in combination with oxides of nitrogen.

Implementation plan—a state blueprint of the steps that will be taken to ensure attainment of an air quality standard within a specified time period.

Inversion—the phenomenon in which a layer of cool air is trapped by a layer of warmer air above it so that the botton layer cannot rise.

Margin of safety—the difference between an allowable level for a given pollutant and a criteria level at which adverse effects have been noted, assuming that the allowable level is numerically lower. Significance is normally expressed in units of 5, e.g., 75 $\mu g/m^3$, 80 $\mu g/m^3$, 85, etc., rather than in units of 1 or 2 $\mu g/m^3$.

Mean—see: arithmetic mean, geometric mean.

Micrograms per cubic meter ($\mu g/m^3$)—a weight per unit volume measurement. Micro is a prefix meaning 1/1,000,000.

Monitoring—sampling by local, state, and regional agencies as part of a surveillance system for measuring pollutants present in the atmosphere or pollutants emitted from an individual point source, e.g., a factory stack.

Oxide—a compound of two elements, one of which is oxygen.

Ozone (O_3)—a pungent, colorless, toxic gas; one component of photochemical smog.

Parts per million (ppm)—a volume unit of measurement; the number of parts of a given substance in a million parts of air.

Photochemical process—the chemical changes and interactions brought about by the radiant energy of the sun acting upon foreign substances in the air. Results in smog.

Point source—a stationary source that emits a given pollutant in amounts above specified levels (such as 25 tons per year).

Ringelmann charts—a series of charts, scaled from 0 to 5, for measuring the density of black smoke rising from stacks and other sources (5 is the most dense, 0 the least). These charts are often used in setting emission standards and checking on compliance.

Scrubber—a device that uses a spray to remove aerosol and gaseous pollutants from an air stream; used for both measurement and control of pollution.

Smog—the irritating haze resulting from the sun's effect on certain pollutants in the air, notably those from automobile exhaust. (Also a mixture of smoke and chemical "fog.")

Source—see: point source, area source.

Standard of performance—an emission limitation imposed on a particular category of pollution sources, either by EPA or by a state. Limitations may take the form of emission standards or of requirements for specific operating procedures.

Sulfur dioxide (SO_2)—a heavy, pungent, colorless gas formed primarily by combustion of coal, oil, and other sulfur-bearing compounds, but also produced in chemical plants and by processing metals and burning trash.

Surveillance system—a required part of implementation plans, established to monitor all aspects of progress toward attainment of air quality standards and to identify potential episodes of high pollutant concentrations in time to take preventive action. Also, the ambient monitoring network.

Synergism—the cooperative action of separate substances in such a way that the total effect is greater than the sum of the effects of the substances acting independently.

Troposphere—the innermost part of the 12-mile layer of air encircling the earth; it extends outward about 5 miles at the poles and 10 at the equator.

Variance—sanction granted by a governing body for delay or exception in the application of a given law, ordinance, or regulation.

West-Gaeke method (modified)—a colorimetric technique for measurement of sulfur dioxide and sulfite salts which can be modified to compensate for interferences produced by the presence of nitrogen oxides, ozone, or heavy metal salts in the sample. (EPA prefers the modified method.)

NOTES ON POLLUTANTS

CLASSIFICATION OF POLLUTANTS *

Major classes	*Sub-classes*	*Typical members of sub-classes*
ORGANIC GASES	Hydrocarbons	Methane, butane, octane, benzene, acetylene, ethylene, butadiene
	Aldehydes & Ketones	Formaldehyde, acetone
	Other organics	Chlorinated hydrocarbons, benzopyrene, alcohols, organic acid
INORGANIC GASES	Oxides of nitrogen	Nitrogen dioxide, nitric oxide, nitrous oxide
	Oxides of sulfur	Sulfur dioxide, sulfur trioxide
	Oxides of carbon	Carbon monoxide, carbon dioxide
	Other inorganics	Hydrogen sulfide, hydrogen fluoride, ammonia, chlorine
PARTICULATES	Solid particulates	Dust, smoke
	Liquid particulates	Mist, spray

* Modified from a table in *Elements of Air Quality Management*, U.S. Department of Health, Education and Welfare, August 1967.

WHAT WE KNOW ABOUT OXIDES OF SULFUR

Major source: fuel combustion

Minor sources: chemical plants, metal processing, trash burning

Nature: Sulfur is a nonmetallic element found in coal and fuel oil. When these fuels are burned, sulfur joins with oxygen in the air to form gaseous oxides of sulfur, including dioxide (SO_2) and sulfur trioxide (SO_3).

Effects: Sulfur oxides, in combination with moisture and oxygen, can yellow the leaves of plants, dissolve marble, and eat away iron and steel. They can limit visibility and cut down the light from the sun. They can affect man's breathing: at sufficiently high concentrations, sulfur dioxide irritates the upper respiratory tract; at even lower concentrations, when carried on particulates, it appears able to do still greater harm by injuring lung tissue.

Conclusions found in the federal criteria document: The criteria *Resumé* for sulfur oxides reports that increased mortality occurred when the annual geometric mean was as high as 115 micrograms per cubic meter. Adverse effects can be detected when SO_x pollution exceeds certain levels for short periods of time. These effects are especially evident in the case of sulfur dioxide. Levels of 300 micrograms per cubic meter of SO_2 for three or four days have been associated with a variety of adverse health effects.

WHAT WE KNOW ABOUT PARTICULATE MATTER

Source: Pollutants can exist as solid matter, liquid droplets, or gas. Both the solid and liquid matter are called particulates (which simply means particles in the atmosphere). Solid particulates consist of dust, smoke or fumes; liquid particulates are mists and sprays. Particulate pollution results from many kinds of industrial and agricultural operations and from combustion products, including automobile exhausts.

Effects: Particulate matter in the respiratory tract may produce injury by itself, or it may act in conjunction with gases, altering their sites or their modes of action. Particles suspended in the air scatter and absorb sunlight, reducing the amount of solar energy reaching the earth, producing hazes and reducing visibility. Particulate air pollution causes a wide range of damage to materials. It may chemically attack materials through its own intrinsic corrosivity or through the corrosivity of substances absorbed or adsorbed by it. Merely by soiling materials and thereby necessitating more frequent cleaning, particulates can accelerate deterioration.

Conclusions found in the federal criteria document: The criteria *Resumé* reports that adverse health effects were noted when the annual geometric mean for particulate matter reached 80 micrograms per cubic meter.

WHAT WE KNOW ABOUT CARBON MONOXIDE

Major source: internal combustion engines in motor vehicles, primarily the automobile

Minor sources: various industrial processes, solid waste disposal

Nature: Carbon monoxide, an invisible, odorless, and tasteless gas, is formed when any carbon-containing fuel (gasoline, coal, and so on) is not completely burned to carbon dioxide (CO_2), but only half-way to carbon monoxide (CO). Because of its characteristics, the internal combustion engine, especially in cars, is responsible for by far the largest fraction of man-made emissions of carbon monoxide.

Effects: Compared to other common air pollutants, carbon monoxide has a unique mechanism of action. It does not irritate the respiratory tract but rather passes through the lungs directly into the blood stream. There it combines with the red blood cell's hemoglobin, the substance that normally carries oxygen to all the tissues of the body. Because hemoglobin binds carbon monoxide over 200 times as strongly as oxygen, a low concentration of carbon monoxide in the ambient air has a greatly magnified effect on the body. Since the heart and brain are the two tissues most sensitive to oxygen deprivation, they show the most serious effects from carbon monoxide exposure. Thus at high concentration (1000 ppm and more), carbon monoxide kills by paralyzing normal brain function. At much lower levels, effects on these two tissues are also the predominate ones (see below).

Because of its unique mode of action, carbon monoxide is not known to have adverse effects on vegetation, visibility, or material objects.

Conclusions found in the federal criteria document: The criteria *Resumé* reports that exposure to 35 mg/m^3 (30 ppm) will, after a few hours, inactivate about 5% of the blood's hemoglobin, thus lowering its oxygen content. This loss can impair performance on certain psychomotor tests, indicating a significant effect on brain function. At higher exposures, excess strain is put on patients with heart disease. Exposure to 12-17 mg/m^3 (10-15 ppm) for several hours also affects the brain by altering time interval discrimination. In addition, there is some very preliminary evidence that at even lower weekly average levels of carbon monoxide (9-16 mg/m^3 or 8-14 ppm), people hospitalized for heart attacks have increased death rates.

WHAT WE KNOW ABOUT PHOTOCHEMICAL OXIDANTS

Nature: Photochemical oxidants are several different pollutants (notably ozone and a group of chemicals called peroxyacylnitrates or PAN) which can come from several sources. All of these pollutants share three properties:

1. They are all formed by the chemical reaction of other pollutants ("-chemical").
2. The reactions forming them proceed much more rapidly in areas with intense sunlight ("photo-").
3. They are extremely reactive chemical substances, acting as oxidizing agents ("oxidants").

Among the most effective combinations for producing this class of pollutants are the oxides of nitrogen and reactive hydrocarbon (organic) vapors. Los Angeles, with its sunny climate and high number of cars, offers extremely good conditions for the production of photochemical oxidants, and in fact this pollution comprises the main part of that city's infamous smog. It is not confined to Los Angeles, however. The constitutents of photochemical smog can now be readily detected in many metropolitan areas.

Effects: The various components of photochemical oxidants can have several adverse effects. First, they can directly affect the lungs and eyes of people, causing respiratory irritation and possibly changes in lung function, as well as subjective eye irritation. They are extremely toxic to many kinds of plants, affecting primarily the leaves. In addition, they can physically weaken such materials as rubber and fabrics.

Conclusions found in the federal criteria document: The criteria *Resumé* for photochemical oxidants reports impairment of the performance of student athletes occurred over a range of hourly oxidant levels from 60-590 μg/m^3 (0.03-0.3 ppm). Increased frequently of attacks in some people with asthma have been observed when hourly averages, as determined from peak measurements, were 100-120 μg/m^3 (0.05-0.06 ppm). Eye irritation occurs in people at once upon exposure to about 200 μg/m^3 (0.10 ppm); this is roughly equivalent to an hourly average of 60-100 μg/m^3 (0.03-0.05).

Adverse effects on vegetation have been noted at levels of about 100 μg/m^3 (0.05 ppm) maintained for four hours. Damage to materials, while clearly observed at levels present in many cities, has not been accurately quantitated at this time.

WHAT WE KNOW ABOUT HYDROCARBONS

Major source: internal combustion engines in motor vehicles, primarily the automobile

Minor sources: evaporation of organic solvents (from painting, dry cleaning, etc.), agricultural burning, gasoline marketing

Effects: At levels of hydrocarbons currently measured in urban areas, no adverse human effects are known to be caused by the hydrocarbons in isolation. However, as discussed in the section on photochemical oxidants, hydrocarbons are an extremely important component of photochemical oxidants, whose effects have been observed. Thus the effects of photochemical oxidants can be, in part, traced back to the hydrocarbons. These, outlined earlier, include respiratory irritation, plant damage, and damage to materials.

Certain specific hydrocarbons do have other effects. Ethylene, for example, damages plants; it can inhibit growth and cause the leaves and flowers to fall.

Conclusions found in the federal criteria document: The criteria *Resumé* clearly states that damaging levels of photochemical oxidants are directly related to concentrations of hydrocarbons in the air which are, if alone, without effect. The *Resumé* states that hydrocarbon concentrations (excluding methane) of 200 μg/m^3 (0.3 ppm as carbon) for three hours may produce photochemical oxidant levels of up to 200 μg/m^3 (0.10 ppm) a few hours later. If the relationship holds true at lower levels of photochemical oxidant known to be damaging, the hydrocarbon concentration that may be associated with adverse effects is about 100 μg/m^3 (0.15 ppm).

WHAT WE KNOW ABOUT OXIDES OF NITROGEN

Major source: fuel combustion

Minor source: chemical plants

Nature: Nitrogen gas, normally a relatively inert (unreactive) substance, comprises about 80 percent of the air around us. At high temperatures (and also under certain other conditions), it can combine with the oxygen in the air to form several different gaseous compounds collectively called the oxides of nitrogen (NO$_x$). Nitric oxide (NO) and nitrogen dioxide (NO$_2$) are the two most important.

Effects: Until recently, it has been difficult to obtain equipment that can detect the oxides of nitrogen in polluted air. Therefore, less is known about these effects than is known, for example, about the effects of oxides of sulfur. Nevertheless, it is clear that the oxides of nitrogen can, at certain concentrations, cause serious injury to vegetation, including the bleaching or death of plant tissue, the loss of leaves, and a reduced growth rate. Oxides of nitrogen can also cause fabric dyes to fade and fabrics themselves to deteriorate. Nitrate salts, formed from the oxides of nitrogen, have been associated with the corrosion of metals. Finally, NO$_x$ can reduce visibility.

Certain members of this group of pollutants are known to be highly toxic to various animals, as well as to man. High levels can kill; lower levels affect the delicate structure of lung tissue. This leads, in experimental animals, to a lung disease that resembles emphysema in man. Exposure to NO$_x$ lowers the resistance of animals to such diseases as pneumonia and influenza; the same may possibly occur in man. Exposure to high levels causes humans to suffer lung irritations and potential damage. Exposure of people to lower levels has been associated with increased respiratory disease.

In addition, oxides of nitrogen, in the presence of sunlight, can react with hydrocarbons to form photochemical oxidants.

Conclusions found in the federal criteria document: The criteria *Resumé* states that a higher incidence of chronic bronchitis has been found in children living in areas where daily averages of NO$_2$ varied from 118 to 156 μg/m^3 (0.062 to 0.083 ppm) and where nitrate salts in the air were also at elevated levels. Adverse effects on plants have been observed when NO$_2$ levels exceed 470 μg/m^3 (0.25 ppm) for several months. Corrosion and damage to electrical equipment has occurred when elevated levels of nitrate salts and NO$_x$ levels of 124 to 158 μg/m^3 (0.066 to 0.084 ppm) were present. Limited evidence suggests that somewhat higher levels of NO$_x$ (roughly 214 μg/m^3 or 0.11 ppm) in the morning hours may be associated, under certain conditions, with the production later in the day of photochemical oxidant levels harmful to human health.

Notes on Hazardous Air Pollutants (See Chapter 6)

WHAT WE KNOW ABOUT ASBESTOS

Asbestos is basically a fibrous mineral substance. Because the fibers are extremely small, they may be inhaled deep into the lungs if they become airborne. It has been known for some time that exposure to high levels of asbestos fibers over a period of years causes a serious chronic lung condition called asbestosis. This disease, which is common among asbestos miners, is similar to the "black lung" disease found among coal miners. It is caused by the accumulation of relatively large amounts of fibrous asbestos which physically obstruct the lung's air passages and in other ways damage its ability to function.

More recently it has been found that individuals exposed for perhaps two decades to levels of asbestos that are not high enough to cause asbestosis may develop other medical problems. Specifically, the incidence of cancer—including an otherwise rare form of lung cancer called mesothelioma—is markedly increased in individuals so exposed. Effects of exposure to asbestos have been closely studied among workmen who spray asbestos-containing insulation onto the girders of skyscrapers as a fire-proofing technique.

There are some clear indications that individuals more indirectly exposed to airborne asbestos fibers also may be endangered. For example, construction workers who do not directly use asbestos (plumbers and electricians, for example) may nonetheless be exposed to elevated levels of asbestos fibers if they are working near the men spraying asbestos-containing insulation. Similarly, those people who have an asbestos miner in their family or who live in a town with an asbestos mine or processing facility are exposed to elevated levels of asbestos dust. Some individuals in these areas have developed the rare form of lung cancer mentioned above.

One of the most interesting aspects of asbestos-caused disease is that the final disease state does not develop until after years or even decades of exposure. Because of this, it is not known whether there is clearly a "safe" level of exposure; indeed, it would be extraordinarily difficult to determine whether such a level exists. This uncertainty has influenced EPA's decision to classify asbestos as a "hazardous" air pollutant as defined by the 1970 Amendments. The agency's concern has undoubtedly been reinforced by the discovery within recent years that from one-fourth to one-half of the lungs of urban Americans contain detectable "asbestos bodies"—asbestos fibers coated by the body in an attempt to isolate them from the surrounding cells.

Of course, this large a fraction of the American population has not been exposed to asbestos due to their occupations. Instead it is due to the presence in the ambient air of asbestos fibers from the construction and demolition of buildings with asbestos-containing insulation, the erosion of asbestos-containing materials (such as brake linings and even certain fabrics), and other such sources. The regulation of asbestos under the Act's hazardous-pollutant provisions may help to minimize the amount of asbestos in the ambient air and the resulting potential risk to human health.

WHAT WE KNOW ABOUT BERYLLIUM

Beryllium—as well as other substances made from it—is very dangerous to human beings. In fact, a report on this pollutant prepared for the federal government, stated that "Beryllium is among the most toxic and hazardous of the nonradioactive substances being used in industry." Beryllium and its derivatives are not a major item of commerce, though they are very important components in certain metal alloys and rocket fuels.

As is often the case with air pollutants, people employed in industrial facilities using beryllium were the first to develop diseases traceable to this substance. Therefore, much of the available information on the effects of beryllium on humans comes from the field of industrial hygiene.

Two types of diseases have been traced to exposure to air-borne beryllium: one, an acute (or short-term) disease lasting up to a few weeks; and two, a chronic (or permanent) condition, often called berylliosis. Both conditions may cause death.

If the acute disease is caused by extremely large exposures, death may occur rapidly due to serious, massive lung damage. A less serious acute condition may cause lung damage, generalized weakness, and a loss of weight. Skin conditions, such as rashes or ulcers, may also occur.

The chronic disease berylliosis may not develop until after months or years of exposure. This is a long-lasting disease with a high mortality rate. It involves the lungs and many other tissues, since beryllium has the ability to interfere with basic biochemical processes in many cells of the body. Lung damage is usually serious and permanent. It often leads to death. Animal experiments suggest that continued exposure to beryllium may result in cancer.

Workers are not the only people who have developed beryllium-caused diseases. Residents of communities where facilities that use beryllium are located have also developed diseases traceable to beryllium exposure. In some cases, another family member worked in the facility and, presumably, brought dust home on his clothing. In other cases, people developing berylliosis had no connection with the plant except that they lived within a few miles of it. Yet air-borne beryllium apparently was present at high enough levels to make them seriously ill. Thus it seems that the presence of beryllium in any community's air carries with it the clear risk that serious, permanent and possibly fatal disease will be contracted by residents. The recognition of this risk has led EPA to declare beryllium a hazardous air pollutant.

WHAT WE KNOW ABOUT MERCURY

Mercury, in any of its chemical forms, is a very toxic metal. Exposure to high levels of this pollutant can result in very serious damage to many organs of the body, particularly to the brain and the kidneys. It can result in death. Exposure to lower levels of mercury can also have serious effects, especially on the brain. The expression "mad as a hatter" was coined to describe the aberrations found in people who worked in the hat-making industry when mercury was used to treat felt.

Several outbreaks of mercury poisoning have been well documented within the last few years. These have involved industrially exposed workers as well as members of the general public. Two general conclusions may be drawn from these events. First, no matter what the specific source of mercury is, the effects on human beings (and even on unborn babies when the mother is exposed) are all very much the same if the exposure is high enough. Second, there is no general agreement on what the "safe" level of mercury in food or air is.

In fact, there are very few data on the effects of long-term exposure to low levels of mercury in the air. What meager data there are do not allow the establishment, with any confidence, of an allowable intake of this contaminant that will protect an entire population.

Some recent findings indicate that air-borne mercury may be a significant source of mercury contamination of other parts of the environment, such as water. Mercury is mobile in the environment and once released may cycle between air, land, and water for long periods of time. Many activities release mercury into the air. Two common fuels—coal and oil—contain small amounts of naturally occurring mercury. When these fuels are burned, much of this mercury is vented into the air. Some kinds of paper are often treated with mercury during manufacture. When the paper is burned after its use (in a municipal incinerator, for example), mercury is released. These sources supplement the major industrial sources of mercury such as the processing of mercury-containing ore and chlor-alkali plants producing mercury cells.

Lack of knowledge about the release of mercury into the atmosphere and its effects, as well as the difficulty of controlling mercury emissions from the combustion of fuels, has led EPA to propose emission standards only for the major industrial sources of atmospheric mercury pollution. The agency has indicated that it is investigating other sources of mercury contamination and will revise and expand its regulations as more knowledge becomes available.

BIBLIOGRAPHY

The following is a list of some of the more important writings about air pollution control. Sources and prices are given wherever possible.

For convenience, each source has been placed under a general heading. The classification is often arbitrary, however. For instance, **Governmental Approaches to Air Pollution Control** has been listed under the "Public Policy and Administration" section. It could also be placed in the "Economics" section, since a good portion of the study deals with economics.

Publications available from the Government Printing Office (GPO) can be ordered from the Superintendent of Documents, Government Printing Office, Washington, D.C. 20402.

Publications available from the National Technical Information Service can be ordered from NTIS, 5282 Port Royal Road, Springfield, Virginia 22151. You *must* cite the publication number when ordering.

EPA also distributes informational materials. Copies of EPA standards and other regulations are generally available free of charge. Check with your regional public affairs office or write to EPA, Office of Public Affairs, Washington, D.C. 20460.

GENERAL INFORMATION

Air Pollution Primer, National Tuberculosis and Respiratory Disease Association, 1969. A useful handbook that explains air pollution's processes, sources, characteristics, and effects. Special sections on weather and radioactivity; glossary. (Available from local Tuberculosis Associations; inquire about price.)

Air Pollution Workbook, Scientists' Institute for Public Information, 1970. Clear, concise explanations of the atmosphere, characteristics of specific pollutants, biological effects of pollution; short, good bibliography and references. (Available from SIPI, 30 East 68th Street, New York, New York 10021. Single copies, $1.00. Multiple rates available.)

A Congregation of Vapors, League of Women Voters, 1970. Good six-page summary of the nature and effects of air pollution and some of the problems associated with controlling it. (Available from LWV of the U.S., 1730 M Street, N.W., Washington, D.C. 20036 for 35 cents. Ask for publication 693.)

LAW, PUBLIC POLICY AND ADMINISTRATION

Clean Air Amendments of 1970, Public Law 91-604. The basic document; sets the national policy for air pollution control; defines the complex federal-state-regional-local responsibilities. (Available free from EPA, or may be purchased from GPO for 20 cents.)

National Environmental Policy Act, Public Law 91-190. Defines the federal policy for protection of the environment; requires federal agencies to evaluate and report on all major proposed actions that affect the environment. (Available from GPO for 10 cents.)

Freedom of Information Act, Public Law 90-23. Establishes the right of public access to federal information; defines the kinds of information to be considered public and agency responsibilities in responding to requests. (Available from GPO for 5 cents.)

Environmental Quality—1971, second annual report of the Council on Environmental Quality. Treats wide range of environmental activities by all levels of government; briefly discusses the economy and the law in relation to environmental concerns, including air, water, solid waste. (Available from GPO for $2.00; publication No. 4111-0005.)

Report of the Senate Committee on Public Works, September, 1970. Explains the rationale underlying the 1970 Clean Air Amendments; strongly expresses the legislative intent in regard to air pollution control. (Available from GPO; publication No. 90-1196. Inquire about price.)

Governmental Approaches to Air Pollution Control, Institute of Public Administration, July, 1971. Brief listing of federal air pollution control programs, discussion of voluntary compliance, emission standards, private legal action; valuable chapters on cost sharing, economic incentives; emission charges; excellent bibliography. (Available from NTIS for $6.00, publication No. PB 203111.)

Managing the Environment: 9 States Look for New Answers, Elizabeth Haskell, Woodrow Wilson International Center for Scholars, April, 1971. Describes and evaluates trends in environmental management by state governments, examines the policies and problems in Illinois, Maine, Maryland, Michigan, Minnesota, New York, Vermont, Washington, and Wisconsin. (Available from the Woodrow Wilson International Center for Scholars, Smithsonian Institution, Washington, D.C. 20560. Inquire about price.)

The Damned Information, Julius W. Hobson, June, 1971. Text of the federal Freedom of Information Act, directions on requesting information under it, sample pleadings from lawsuits, listing of each state's information act, bibliography. (Available from the Washington Institute for Quality Education, 300 M Street, S.W., Washington, D.C. 20024 for $3.75.)

ECONOMICS

The Economics of Clean Air, annual report of the EPA Administrator, March, 1971. Summarizes EPA studies on costs of government control programs, on their impacts on 17 selected industries, and on U.S. price structures. Invaluable. (Available from GPO for $1.00, publication No. 92-6.)

The Economics of Air Pollution, Harold Wolozin, ed. Collection of papers on the economics of air pollution control, research, and policy formulation commissioned for a symposium on national economic policy. Useful theoretical study, though some portions are now outdated. (W.W. Norton & Co., New York, 1966. $10.00.)

CITIZEN ACTION

Action for Clean Air: a manual for citizen participation in state implementation plan proceedings under the Clean Air Amendments of 1970, Natural Resources Defense Council, 1971. Explains in detail the Act and EPA's regulations for implementation plans; makes specific suggestions for action by individuals and by organized citizen groups. Emphasizes legal procedures and citizens' legal rights. (Available free from NRDC, 36 West 44th Street, New York, New York 10036.)

Selected Air Pollution Topics: a Citizen's Resource, Scientists' Institute for Public Information, 1971. A layman's guide to sources of technical, scientific and economic information. Gives basic explanations of available control technology, cost factors and efficiencies. Valuable reference work. (Limited number of copies available in manuscript form from SIPI, 30 East 68th Street, New York, New York 10021 for $1.50.)

Your Right to Clean Air, Conservation Foundation, 1970. First version of this manual; outdated section treats air quality processes under the previous (1967) Act; section on organizing citizen clean air coalitions still timely for persons beginning this process. (A few copies are still available for such persons. Please specify 1970 pamphlet when writing to the Foundation. Copies are free.)

TRANSPORTATION

Governmental Approaches to Automobile Air Pollution Control, Institute of Public Administration, March, 1971. Discusses industry's control of auto emissions, consumer control, advantages and disadvantages of standard-setting, of emission charges, of traffic system designs. (Available from NTIS for $3.00, publication No. PB 203-952.)

The Pavers and the Paved, Ben Kelley, 1971. Well-documented examination of federal highway programs, funding and operations; includes a guide to halting highways; suggests ways to change transportation priorities; good bibliography. (Donald Brown Inc., New York, $5.95.)

Superhighway—Superhoax, Helen Leavitt, 1970. A polemic, crammed with facts about federal highway programs, funding and operations; cites dozens of problems and issues in localities throughout the U.S.; special chapter on urban highway problems; ihformation on alternative transit systems. (Ballantine paperback, 95 cents.)

TECHNICAL INFORMATION

Air Quality Criteria for Particulate Matter; Air Quality Criteria for Sulfur Oxides; Air Quality Criteria for Carbon Monoxide; Air Quality Criteria for Hydrocarbons; Air Quality Criteria for Photochemical Oxidants; Air Quality Criteria for Nitrogen Oxides, EPA. Massive compilations of most of the known data on these pollutants, including relations of various levels and combinations to detectable effects on health, materials, vegetation, and so on. (Available from GPO; inquire about prices. State and local air pollution control agencies should have copies on open file for public inspection. Also, EPA distributes brief, readable "Summary Chapters" from each criteria document; these summaries are free.)

Control Techniques for Particulate Air Pollutants; Control Techniques for Sulfur Oxide Air Pollutants; Control Techniques for Carbon Monoxide, Nitrogen Oxide, and Hydrocarbon Emissions from Mobile Sources; Control Techniques for Hydrocarbon and Organic Solvent Emissions from Stationary Sources; Control Techniques for Nitrogen Oxide Emissions from Stationary Sources, EPA. Compendia of known, tested methods for controlling these pollutants, including changes in production processes, collection of emissions, chemical and physical modifications, and so on. (Available on the same basis as *Criteria* documents.)

Air Pollution, Arthur C. Stern, ed., second edition, 3 vol. The most authoritative, comprehensive work available. Highly technical. (Academic Press, New York and London, 1968, $115.00.)

Cleaning our Environment: the Chemical Basis for Action, American Chemical Society, 1969. Brief up-to-date summary of what is known and unknown about air pollution, recommendations for control and for research, valuable report on inadequate use of current control technology. (Available from ACS, 1155 16th Street, N.W., Washington, D.C. 20036 for $2.75.)

ADDRESSES FOR AGENCIES AND ORGANIZATIONS

Environmental Protection Agency
Waterside Mall
4th & M Streets, SW
Washington, D.C. 20460

Federal Communications Commission
1919 M Street, NW
Washington, D.C. 20554

Federal Trade Commission
Pennsylvania Avenue at 16th Street, NW
Washington, D.C. 20580

ENVIRONMENTAL PROTECTION AGENCY REGIONAL OFFICES

REGION I

Connecticut, Maine, Massachusetts, New Hampshire, Rhode Island, Vermont
John F. Kennedy Federal Building
Boston, Massachusetts 02203

REGION II

New Jersey, New York, Puerto Rico, Virgin Islands
26 Federal Plaza
New York, New York 10007

REGION III

Delaware, Maryland, Pennsylvania, Virginia, West Virginia, District of Columbia
Curtis Building
6th & Walnut Streets
Philadelphia, Pennsylvania 19106

REGION IV

Alabama, Florida, Georgia, Kentucky, Mississippi, North Carolina, South Carolina, Tennessee
1421 Peachtree Street, N.E.
Atlanta, Georgia 30309

REGION V

Illinois, Indiana, Michigan, Minnesota, Ohio, Wisconsin
1 N.W. Wacker Drive
Chicago, Illinois 60606

REGION VI

Arkansas, Louisiana, New Mexico, Oklahoma, Texas
1114 Commerce Street
Dallas, Texas 75202

REGION VII

Iowa, Kansas, Missouri, Nebraska
911 Walnut Street
Kansas City, Missouri 64106

REGION VIII

Colorado, Montana, North Dakota, South Dakota, Utah, Wyoming
Lincoln Tower Building
1860 Lincoln Street
Denver, Colorado 80203

REGION IX

Arizona, California, Hawaii, Nevada, American Samoa, Guam, Trust Territories of Pacific Islands, Wake Island
760 Market Street
San Francisco, California 94102

REGION X

Alaska, Idaho, Oregon, Washington
1200 Sixth Avenue
Seattle, Washington 98108

ORGANIZATIONS TO CONTACT FOR ASSISTANCE

Citizens Communications Center
1816 Jefferson Place, NW
Washington, D.C. 20036

Concern, Inc.
2233 Wisconsin Avenue, NW
Washington, D.C. 20007

Council on Economic Priorities
26 Beaver Street
New York, New York 10004

Environmental Action, Inc.
1346 Connecticut Avenue, NW
Washington, D.C. 20036

Highway Action Coalition
Room 731
1346 Connecticut Avenue, NW
Washington, D.C. 20036

League of Women Voters of the U.S.
1730 M Street, NW
Washington, D.C. 20036

Natural Resources Defense Council
36 West 44th Street
New York, New York 10036

National Tuberculosis &
Respiratory Disease Association
1740 Broadway
New York, New York 10019

Scientists' Institute for
Public Information
30 East 68th Street
New York, New York 10021

OTHER ADDRESSES

Commerce Clearing House, Inc.
4025 West Peterson Avenue
Chicago, Illinois 60646

National Association of Manufacturers
1133 15th Street, NW
Washington, D.C. 20005